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C H Y M I S T R Y

APPLIED TO

A G R I C U L T U R E.

BY M. LE COMTE CHAPTAL,
MEMBER OF THE FRENCH INSTITUTE, ETC., ETC.

WITH A PRELIMINARY CHAPTER
ON THE ORGANIZATION, STRUCTURE, ETC., OF PLANTS;
BY SIR HUMPHREY DAVY.

AND AN ESSAY
ON THE USE OF LIME AS A MANURE,
BY M. PUVIS;

WITH INTRODUCTORY OBSERVATIONS TO THE SAME,
BY JAMES RENWICK, LL.D.

TRANSLATED AND EDITED
BY REV. WILLIAM P. PAGE.

NEW-YORK:
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P R E F A C E.

It is certainly not a little surprising, that while so many of the useful arts have been vastly improved, and some seemingly almost perfected, by the applications of physical science, agriculture, though immeasurably the most important of all, should still be in a state of comparative rudeness; and its operations but too generally conducted with scarcely the smallest reference to the natural laws. One might, indeed, from seeing this, be almost led to suppose, that its successful prosecution was considered as being, in no considerable degree, dependant upon the observance of these laws; whereas, in fact, there is not a single phenomenon in vegetation that is not produced by them, and the operations of the agriculturist have no other effect than either to develop, or to modify their action. It will appear therefore abundantly evident, that, in order to perfect his art, the farmer must conform his practice to those unchanging principles, which have been deduced from observation of the nature and results of the physical laws. There is nothing then so indispensable to the interests of agriculture, as that the knowledge of these laws should

be more widely diffused ; and it is solely with a view of contributing, according to his best ability, toward the accomplishment of so important an object, that the translator and compiler of this volume is induced to present it to the public.

Nor let it be supposed that the truths of physical science are either so abstruse, or so difficult of application, as to be without use to the practical farmer. "There is," says Davy, "no idea more unfounded than that a great devotion of time, and a minute knowledge of general chymistry, is necessary for pursuing experiments on the nature of soils or the properties of manures. Nothing can be more easy than to discover whether a soil effervesces, or changes colour by the action of an acid, or whether it burns when heated, or what weight it loses by heat ; and yet these simple indications may be of great importance in a system of cultivation. The expense connected with chymical inquiries is extremely trifling. The most important experiments may be made by means of a small portable apparatus ; a few vials, containing acids, alkalies, and chymical re-agents ; some foil and wire of platinum ; a lamp, a crucible, some filtrating paper, some funnels and glasses, for receiving products, are all that can be considered as absolutely essential for pursuing useful researches." But there will also be found contained in this volume, a very great number of most important facts and principles, of which the intelligent farmer will be able to avail himself, without any necessity of resorting to experiments.

There is, in truth, no sentiment more unfounded, than that knowledge is necessarily confined to a favoured few; while the many are, by the circumstances of their condition, unavoidably precluded from its pursuit. This unworthy and degrading sentiment, the prevalence of which has been hitherto so fatal to the progress of human improvement, is happily fast giving way before the increasing light and intelligence of the age; and there is at length opening up to the contemplation of man, whatever may be his condition in society, or his lot in life, more just and ennobling views of his destination, his true happiness, and the capabilities of his nature.

The increasing attention everywhere given to the subject of education, the efforts so strenuously put forth for its improvement, and though last, not least, the noble example presented by our own state, in its munificent provision for the universal diffusion of knowledge by means of School District Libraries, afford to us the happiest auguries for the future; and may we not confidently anticipate that, at no distant day, ignorance will be banished from our land.

These observations it is hoped will not be deemed out of place in the connexion in which they appear. The writer has long felt the deepest concern in the subject to which they relate, and, to the best of his feeble ability, has endeavoured to promote the all-important interests with which it stands connected. He has, therefore, taken great pleasure in preparing this volume for the object for which it is primarily designed, to be placed in the School District Library; nor is

he without a hope, somewhat confidently indulged, that it will prove both interesting and useful to the intelligent farmer.

With the exception of a part of the introduction, and the concluding chapter containing a view of the products of French industry, the whole of the first volume of Chaptal has been translated, and all that seemed to be essential in order to complete the subject of Agricultural Chymistry. The two great names connected with this subject are Chaptal and Davy; and with the view, as far as possible, of uniting in one the most valuable remarks of both these authors, I have not only made liberal use of the latter in the form of notes, but have also employed the most of his first lecture in the introductory chapter of this volume. The Essay on the "Use of Lime as a Manure," by M. Puvis, translated by the able editor of the Farmer's Register, will be found to contain many exceedingly important views; and the introduction to the same, by Professor Renwick, is highly valuable, as presenting in a condensed form, and with great clearness, the principles of chymistry applicable to agriculture. The whole is respectfully submitted to the public, in the hope that it may be, to some extent, useful in promoting the improvement of an art, which may be considered as constituting the basis of the other great interests of society.

New-York, Oct. 1, 1839.

W. P. P.

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ERRA A.

46, l. 13,	for other,	read ether.
50, 27,	wood,	woad.
62, 28,	third,	second.
	33,	second,
101, 10,	semititrifaction,	semivitrifaction.
150, 27,	moisture,	mixture.
160, 5,	cabonate,	carbonate.
176, 19,	recomposition,	decomposition.
183,	241,	247.
215, 1,	limiting,	liming.

INTRODUCTION.

BUT for agriculture, man must have been a mere wanderer about the earth, subsisting on the flesh of such wild animals as he might make his prey, or upon the spontaneous productions of the soil, and even for the possession of these, engaged in frequent conflicts with his fellow-man; there could have been no bonds either of social union, or of country. By localising the means of subsistence, and at the same time ensuring a more certain and abundant supply, agriculture first enabled the inhabitants of the earth to unite themselves into communities for purposes of mutual protection and assistance; so that while some were engaged in cultivating the soil to render it productive, others applied themselves to the different arts which furnish to society, the various mechanical products of which it stands in need. Thus, by reciprocal intercourse, and the beneficial exchange of commodities, commerce was established, and civilization progressively advanced, and perfected.

If the effect of residing in cities, an inactive mode of living, and employment in particular arts, be to enfeeble and enervate one class of mankind, agriculture, on the contrary, preserves in a state of health, strength, and good morals, a far more numerous class, engaged in its pursuit. Nor is this to be reckoned as one of its least benefits, that it should be thus constantly tending to renovate that portion of society, which, from less favourable circumstances, is in a less sound and vigorous condition.

Agriculture is to all nations, the purest and most

certain source of prosperity. Owing to diversity of climate, the vegetable products of the different portions of the earth are almost infinitely varied; but commerce distributes them far and wide, and thus each people is enabled to partake of the productions of every part of the globe. The intercourse in this way established between different nations, has been the means of rendering them dependant upon each other and of uniting them by many friendly ties, of extending the light of civilization and of knowledge, and of awakening everywhere a spirit of intelligence and of industry.

The occupation of the agriculturist, therefore, should entitle him to be considered as holding at once the most honourable and the most useful station in society. By what fatality is it, then, that his condition in France has from time immemorial been so debased and wretched? So deplorable at times has been his situation, that he might envy the lot even of the brute animals associated with him in his toils; and to this state of frightful degradation he was not unfrequently reduced, by the very individuals whom he was sustaining in idleness and luxury, by his labours. What with statute-labour, tithes, and seignoral exactions of every kind, there was nothing left to him for subsistence, but the mere refuse of his crops; he moistened the soil with the sweat of his body, and the fruits which it produced were for the enjoyment of others.

In this state of deepest wretchedness and debasement, the cultivator of the soil blindly and undeviatingly pursued a certain beaten track, marked out for him; without ambition, without intelligence, and almost without so much as the slightest feeling of interest, the idea of improving his methods of culture never even occurred to his mind.

It was only when, by a wise return to the true principles of justice, of humanity, and of public interest, the rights of property came at length to be

acknowledged and protected, taxes fairly and proportionably levied, and immunities abolished, that the agriculturist felt a new energy and spirit awakened within him, and became at length, after ages of almost unconscious debasement, apprised of the importance and the dignity of his occupation. The light of intelligence now began to diffuse itself throughout the country, improved methods of cultivation were introduced and extended, and private and public interest became indissolubly united. At this period, agriculture received a new impulse, and its course has ever since been steadily and rapidly progressive. The nature of soils has come to be better understood; artificial meadows have been greatly extended; a system of succession and interchange of crops, founded on the experience of those countries where agriculture is best conducted, has been introduced; the number of domestic animals has been gradually increased, and, with them, manure and effective tillage, which constitute the basis of successful husbandry.

All that is wanting at the present time, is that agriculture should be enlightened by the application of the physical sciences. All the varied phenomena which it presents, are nothing more than the natural results of those fixed and unchanging laws by which material bodies are governed; and the operations of the agriculturist serve merely to develop or to modify the action of these laws. It is, therefore, to the understanding of the natural laws, the ascertaining of their effects, and the modification of their action, that we are called upon to direct all our enquiries.

And what study, possessing higher attractions, can be offered to the agriculturist; a study, the design of which is to explain to him the causes of those astonishing effects, which daily captivate his senses, and confound his reason. He may, by observation, have traced the progress of nature through all her changes; he may also be able to judge of the modifications effected in relation to her productions, by the condition

of the atmosphere, diversities of climate, and the nature of the soil; and this practical knowledge may even suffice to guide him correctly in his various operations; but, if he may be permitted to ascend from effects to their causes; if we can determine and make known to him the manner in which air, water, heat, light, the soil, manures, &c., act upon plants, and indicate the particular influence, also, which each one of these agents exerts in the grand phenomena of vegetation, how deeply will he be interested! While yet a mere mute observer of all these wonders, they did not fail to excite in him a feeling of admiration; but how immeasurably will this sentiment be increased, when he comes to be acquainted with the causes by which they are produced!

Persuaded that it is only by the application of the physical sciences that agriculture can be progressively improved, and finally perfected, I will, in these introductory remarks, simply state a few general principles, and refer the reader for their development to the body of the work.

The laws of nature are fixed and unchanging. The natural state of bodies, their relations to one another, the changes which they undergo, the phenomena of decomposition and of composition, which animate, and are constantly renovating the surface of the earth, all result from the action of these laws.

Matter, then, in the first place, is governed by two great universal laws, and, by virtue of which, all bodies exist in their natural state. One of these acts upon matter in mass; the other upon the individual particles of which masses of matter are composed. The first is the general law of attraction, the second that of affinity.

The law of affinity, of which alone I propose here to speak, constantly tends to bring more closely in contact the particles of which bodies are composed. If this law operated alone, and its action were absolute and uncontrolled, the density or consistence of

bodies, in their natural state, would depend altogether upon the different degrees of affinity existing between the particles of which they consist. This, however, is not the case. The effects of this law are counteracted and modified by the fluid of heat, which is distributed in unequal proportions throughout all substances, and which is constantly tending to separate from each other the elements, which the law of affinity seeks to unite. Affinity alone would form merely solid masses, wholly inert, and of different degrees of compactness; while, on the other hand, the fluid of heat, if left to itself, would produce nothing but gases, or æriform substances; and it is in consequence of the opposite and simultaneous operation of these two agents, that bodies are either solid, or liquid, or fluid, according to the different degrees of intensity with which they respectively act.

The natural state of bodies is the effect, therefore, of the action of the law of affinity, which unites together their elements, combined with that of the intervening fluid of heat, which is constantly tending to separate them from each other.

The variations in the temperature of the atmosphere at different seasons of the year, are sufficient to produce great changes in the consistence of certain bodies; and thus we see water in a solid, liquid, or æriform state, according to these variations.

Man, by being able at will to employ the fluid of heat, has it in his power to effect very striking changes in the natural state of bodies. He can augment or diminish at pleasure their consistence, and cause them to pass either to a solid, or liquid, or æriform state, according as he may choose to apply more or less of that fluid.

The effects, however, produced by increase or diminution of the fluid of heat, are not permanent. Bodies return to their primitive or natural state, so soon as the cause, which displaced them from it, has ceased to act upon them; and, in doing this, they impart to

other bodies by which they are surrounded, any excess of fluid with which they are impregnated; or, more properly, they resume that which has been taken from them.

These changes of form and consistence do not alter the nature of bodies; but, in separating their particles, or compacting them more closely together, they either diminish or augment their cohesion and affinity, and by this means dispose them to form new combinations.

The principles here laid down are not strictly applicable to animal or vegetable substances, nor to certain other compound bodies, except in such degree as they may be affected by the application of an inconsiderable portion of heat. The constituent elements of these bodies requiring unequal degrees of heat to reduce them to a liquid or gaseous state, it follows that a portion of them may be made to assume one or the other of these forms, by any degree of heat greater than that of the atmosphere; so as to be separated from another portion which will remain, and in which case decomposition is produced.

If the affinity were the same between all the different elementary particles of which bodies are composed, there would be nothing but a simple aggregation of matter, and confusion of products, both in the operations of nature, and for the purposes of art. But each particular element has its appropriate affinities; so that it altogether refuses to combine with some, while it readily contracts the most intimate union with other elements. Thus all bodies are formed, regulated, and arranged, by the different affinities of their constituent elements. The uniform reproduction of the products of nature, and the combinations of art, are both dependant upon this principle.

It follows, then, from these premises, that there can be no durable combination, except between such elements as have a mutual affinity for each other; and that decomposition will take place, whenever there is

presented to a compound body, any element, which, by having a stronger affinity for some one of its constituent principles, thereby displaces another.

It will readily be perceived, then, how important it is, if we would study either the operations of art, or of nature, that we should understand the degrees of affinity between the different elements which may be made to enter into combinations.

Since chymistry disposes at will of nearly all the agents employed by nature, she is enabled to follow in the track of her operations, though she cannot imitate all her productions. She is acquainted with the materials which nature makes use of, and is frequently able to furnish them to her, and thus to facilitate and quicken her action; she can prevent her aberrations, by removing the causes which would occasion them; in a word, the reciprocal action of bodies is controlled by immutable laws; but the chymist, by knowing the respective affinities of these same bodies, is able to dispose of them at pleasure; he can combine them in every variety of proportion, can subject them to every degree of temperature, can separate their parts by the introduction of foreign agents, can augment or diminish the force of each one of these, and can thus effect results, which nature herself, in her steady and uniform movement, fails to produce. It is by means of this power, that chymistry is every day forming new compounds, and that she has enriched industry, and domestic economy, with an immense variety of products, which, but for the aid of this science, must have been for ever unknown.

Rude, inorganic matter is subject to no other laws than those of which I have just spoken. All the changes which it undergoes, all the phenomena which it presents, all the compositions and decompositions by which it is affected, are their work. Chymistry can not only explain, but predict, the results of their action; and she can even form new combinations of her own.

But, while inorganic matter obeys only the laws of affinity, living bodies, in addition to these, are subject to certain other laws, the laws of vitality, which are incessantly engaged in modifying the action of the former. These laws of vitality act with the greater force, they predominate the more over the laws of affinity, in proportion as living bodies are so organized as to possess more of the vital principle. It is for this reason, that, with all our researches, we cannot discover the mode of action in living bodies; and that, though we witness everything which passes within them, we are neither able to explain, nor to imitate their products.

Chymistry is, as yet, limited to a knowledge of the substances which enter into animals and vegetables, to afford to them nourishment; and to studying the operations and effects of the different agents, which contribute to assist them in performing their functions. She knows what substances they appropriate to themselves, and what they reject; but the elaboration of these substances in their organs, the formation of their products, and the manner of their growth, are, and may for ever be, a mystery. It is true that we already know much with regard to the functions of living bodies; but that of which we are still ignorant, greatly exceeds the part which we know.

The laws of vitality, like the other natural laws, are immutable; but the differences of organization in living bodies so vary and modify their action, as to diversify the products in every species, and even in each one of their different organs. This almost infinite variety of productions may well surprise us, and more especially if we consider that the same forms and qualities are uniformly renewed, every year, and with each successive generation.

The laws of organization, then, have established bounds beyond which science has, as yet, been unable to pass. Nevertheless, she has succeeded in unfolding certain sublime pages of living nature, and

she has made numerous and useful applications of them.

The living plant, fastened by its roots immoveably in the soil, has no power of locomotion to go in quest of the substances by which it must be nourished. It obtains, therefore, all its aliment from the earth and air with which it is immediately encompassed; these aliments it elaborates in its organs, decomposes them, and always combines their elements in the same uniform manner.

With regard to plants when dead, it is widely different. Bodies of every description exert upon them, then, an uncontrolled physical action. The effects of this action are no longer modified by the laws of organization; the very same agents, as air, water, heat, &c., which nourished and sustained them, while living, now powerfully co-operate in their decomposition; and there are no means of preventing this disorganization from going on until it is complete, but by withdrawing them entirely from the contact and action of these agents.

Here chymistry resumes all her prerogatives. She knows all the elements which enter into the composition of the dead plant, and the degrees of affinity by which these elements are united; and she can foresee the changes which will be produced by the various external agents which she has at her control, and whose action she can modify at will.

It is in this state of things, that I have supposed that chymical knowledge may be applied with the most signal advantage to agriculture. It very plainly appears to me, that, by better understanding the nature and properties of the bodies with which we operate, by combining facts confirmed and sanctioned by experience, with sound theory, and by carefully determining the action and effects of everything which can influence vegetation, we may succeed in establishing principles, which, in their application, cannot

fail to accelerate the progress of the most important of arts.

All the different sciences have one uniform and natural course, from which they can never deviate. Their first step is to bring together and verify numerous facts; and when these have been satisfactorily established, to compare them with each other, and from their agreement, or disagreement, to deduce principles.

The facts with regard to agriculture are already numerous; but, the modifications produced in its results, by the nature of the soil, the action of manures, the state of the atmosphere, the influence of climate, and varieties of exposure, have these been sufficiently verified? A fact observed in one situation, will it uniformly recur in every other?

Insulated facts are not sufficient to establish general principles in agriculture. It is necessary, too, that they should have been observed and verified, and under the influence of all the various agents of which we have spoken; and to know what modifications are effected by each one of these agents, before we can derive from them, such general principles as may be practically applied.

If the agents in vegetation were, indeed, constantly the same, and if their action were everywhere uniform, a single well-observed fact would constitute a principle of universal application. But the difference in their action, under different circumstances, must necessarily modify results. Thus that which causes a particular kind of culture to succeed in one country, will not have the same effect in another; and the agriculturist, in adopting new methods, which are attended with favourable results elsewhere, is often disappointed in his experiments, from the fact that he is unable to combine the same causes of success.

I have, therefore, from all these considerations, been persuaded, that a work upon the principles of agriculture, would possess no substantial value, unless it should make known the properties, and the action of

all the different agents which influence its operations; and, after having done this, I shall only so far treat of the methods of culture ordinarily practised, as to extend the application of my deductions to all the different cases to which they are suited.

The progress of agriculture is slow, and it ought to be so; since wisdom and prudence require that we should not depart from usages consecrated by time, until other methods, to be substituted in their place, have been fairly subjected to trial, and have received the sanction of experience.

The reproach daily cast upon the husbandman, of indifference to new methods of culture, is, in my estimation, not altogether merited. He is desirous, first of all, to see for himself, and, from his own observation, to compare results; since he has, for the most part, neither the knowledge, nor other means, which would be required to enable him to judge in advance, of the advantages proposed to him. He, therefore, adheres to the methods of which he has had experience, until some neighbouring proprietor, possessing greater information and more wealth than himself, exhibits to him a new mode of husbandry, which ensures to him more profitable results than those obtained from his own.

And, besides, the adoption of new methods, whatever in particular cases may be their products, is far from being the only thing to ensure success. In agriculture everything should be done upon calculation, and all its operations should be regulated with rigid reference to expenditure and receipts, as in every other well-reasoned and judiciously conducted undertaking. The most abundant crops may ruin the farmer; for agriculture admits not of profuse expenditure, and she condemns all superfluity, as being of the nature of extravagance and luxury. It is for want of being thoroughly impressed with the truth, and the importance, of these principles, that we every day see some new and unskilled proprietor condemn, without

so much as considering them, usages ascertained to be productive of good results, and consecrated by time; and, at the same time, adopt at great expense new and untried methods, and obstinately persevere, too, in continuing them, though opposed both by soil and climate, until, finally, he concludes his experiments with the abandonment of his lands, and the ruin of his fortune.

Although agriculture has been from time to time enriched by the introduction of new plants from abroad, and, before, strangers to the soil, it is only a small proportion of these foreign productions that she can profitably appropriate to herself; while she must be chiefly solicitous more and more to extend the cultivation of those plants which she already possesses.

A plan of cultivation which is limited to the production of grain alone, contributes but very partially to the wants of the community; but if it embrace, within the compass of its operations, the various productions suited to the climate and the soil, it thereby turns into the workshop of the artisan the materials necessary to industry, and provides for all the necessities of society.

The condition of the husbandman who cultivates only a single production, is always precarious. His prosperity depends not merely upon the chances of crops, but likewise upon the state of prices, and the demand for consumption; while, if he gathers from his soil a variety of products, he is almost certain of advantageously disposing of some of them. Thus it is that, in the south of France, the landed proprietor cultivates not only the crops common to the whole country, but has also his wine, his silk, and his oil; so that an abundant product of one of these will indemnify him for any failure that may chance to befall the rest.

Another advantage which the farmer obtains from the cultivation of a variety of products, is that he is thereby enabled to appropriate to each different soil,

the plants which suit it best; and thus to keep them all in the best condition for vegetation.

And what is, if possible, more important still, the cultivation of various products affords to the farmer immense advantages in carrying out a judicious system of alternating crops; and wherever cultivation is limited to grain alone, it is wholly futile to attempt to establish any such a system. It is only upon a great variety of productions, that any well-combined plan of succession and interchange of crops, can be founded; since this, alone, will keep the soil in a state of unfailing fertility, and enable it to produce without intermission, or exhaustion.

While seeking to enlighten agriculture by the application of the physical sciences, I have endeavoured studiously to avoid those difficulties, which would in a great measure defeat the end which I propose to attain. I have sought, indeed, never to forget, that it was for the agriculturist, especially, that I was writing; and that it was incumbent upon me, therefore, to be always clear, exact, and within the compass of his intelligence, his education, and his pecuniary means. In order that I might make myself the better understood, I have frequently borrowed his language, and have never failed to fortify the principles which I would establish, by the results of his experience.

Persuaded that a process of which the effects are known, is always preferable to the conceptions of mere theory, I have endeavoured constantly to respect the knowledge which has been obtained from practice and experience; and never to propose new methods, except when their superiority to the old has appeared to be sufficiently confirmed, and abundantly evident. It is more especially in agriculture, that we should be cautious in introducing innovations.

This work makes no pretensions to being perfect, and, more than this, I myself know, better than any one else can, what are its imperfections. But, with

all its faults and deficiencies, I think it will be useful. As the physical sciences become more and more advanced, new principles applicable to agriculture will be constantly obtained from them, and thus rectify and replace such as shall prove to be erroneous. The celebrated Davy has already published a treatise on agricultural chymistry, to which I am indebted for many excellent principles; and those who come after us, will do better than we.

Hitherto the applications of the physical sciences to agriculture have been small in number, compared with those which have been employed in the progress of arts infinitely less important, and which have been both originated and perfected, within our own day. This circumstance may, I think, be attributed to two principal causes. The first is, that most of the phenomena which agriculture presents to us, are the effects of those laws of vitality to which the functions of plants are subjected, and with regard to which laws we are entirely ignorant; whereas in the arts which operate only upon rude, inanimate matter, everything is regulated, and everything produced, either by the mere action of the physical laws, or by simple affinity, and both of which are known and understood by us. The second cause is, that, before the sciences can be successfully applied to agriculture, it must be profoundly studied, not only in the closet, but in the field.

Although the proprietor of a large domain of which I have myself directed for many years the cultivation, I consider, nevertheless, that the facts which, during this long experience, I have been able to collect, are yet insufficient to afford incontestable principles; and I have, therefore, been careful in all such cases, to confine myself to the expression merely of doubts, or of probabilities. I may in the course of this treatise be often mistaken in my explanations; but I do not think that I have wrongly stated a single fact; and it is in the confidence thus expressed, that I offer the present work to the agriculturist.

CHYMISTRY

APPLIED TO

AGRICULTURE.

CHAPTER I.

[FROM DAVY'S ELEMENTS OF AGRICULTURAL CHYMISTRY.]

On the organization of plants—Of the roots, trunk, and branches—Of their structure—Of the epidermis—Of the cortical and alburnous parts—Of leaves, flowers, and seeds—Of the chymical constitution of the organs of plants, and the substances found in them—Of mucilaginous, saccharine, extractive, resinous, and oily substances, and other vegetable compounds; their arrangements in the organs of plants, their composition, changes, and uses.

VARIETY characterizes the vegetable kingdom; yet there is an analogy between the forms and the functions of all the different classes of plants, and on this analogy the scientific principles relating to their organization depend.

Vegetables are living structures, distinguished from animals by exhibiting no signs of perception or of voluntary motion; and their organs are either organs of nourishment or of reproduction; organs for the preservation and increase of the individual, or for the multiplication of the species.

In the living vegetable system, there are to be considered the exterior form, and the interior constitution.

Every plant, examined as to external structure, displays at least four systems of organs—or some analogous parts. First, the *Root*. Secondly, the *Trunk and Branches*, or *Stem*. Thirdly, the *Leaves*; and, fourthly, the *Flowers* or *Seeds*.

The *root* is that part of the vegetable which least impresses the eye; but it is absolutely necessary. It attaches the plant to the surface, is its organ of nourishment, and the apparatus by which it imbibes food from the soil. The roots of plants, in their anatomical division, are very similar to the trunk and branches. The root may indeed be said to be a continuation of the trunk, terminating in minute ramifications and filaments, and not in leaves.

When the branch or the root of a tree is cut transversely, it usually exhibits three distinct bodies; the bark, the wood, and the pith; and these again are individually susceptible of a new division.

The bark, when perfectly formed, is covered by a thin cuticle or *epidermis*, which may be easily separated. It is generally composed of a number of laminae or scales, which in old trees are usually in a loose and decaying state. The *epidermis* is not vascular, and it merely defends the interior parts from injury. In forest-trees, and in the larger shrubs, the bodies of which are firm and of strong texture, it is a part of little importance; but in the reeds, the grasses, canes, and the plants having hollow stalks, it is of great use, and is exceedingly strong, and in the microscope seems composed of a kind of glassy network, which is principally siliceous earth.

This is the case in wheat, in the oat, in different species of *equisetum*, and, above all, in the rattan, the *epidermis* of which contains a sufficient quantity of flint to give light when struck by steel; or two pieces rubbed together produce sparks. This fact first occurred to me in 1798; and it led to experiments, by which I ascertained that siliceous earth existed generally in the *epidermis* of the hollow plants.

The siliceous epidermis serves as a support, protects the bark from the action of insects, and seems to perform a part in the economy of these feeble vegetable tribes, similar to that performed in the animal kingdom by the shell of the crustaceous insects.

Immediately beneath the epidermis is the *parenchyma*. It is a soft substance, consisting of cells filled with fluid, having almost always a greenish tint. The cells in the parenchymatous part, when examined by the microscope, appear hexagonal. This form, indeed, is that usually affected by the cellular membranes in vegetables; and it seems to be the result of the general reaction of the solid parts, similar to that which takes place in the honeycomb. This arrangement, which has usually been ascribed to the skill and artifice of the bee, seems, as Dr. Wollaston has observed, to be merely the result of the mechanical laws which influence the pressure of cylinders composed of soft materials, the nests of solitary bees being uniformly circular.*

The innermost part of the bark is constituted by the *cortical layers*, and their numbers vary with the age of the tree. On cutting the bark of a tree of several years' standing, the productions of different periods may be distinctly seen, though the layer of every particular year can seldom be accurately defined.

The cortical layers are composed of fibrous parts, which appear interwoven, and which are transverse and longitudinal. The transverse are membranous and porous, and the longitudinal are generally composed of tubes.

The functions of the parenchymatous and cortical parts of the bark are of great importance. The tubes of the fibrous parts appear to be the organs that receive the sap; the cells seem destined for the elabora-

* My brother told me, that Dr. Wollaston, on further inquiry, relinquished the idea expressed above, and adopted the common opinion regarding the manner in which the hexagonal cells are formed.—J. D.

tion of its parts, and for the exposure of them to the action of the atmosphere; and the new matter is annually produced in the spring, immediately on the inner surface of the cortical layer of the last year.

It has been shown by the experiments of Mr. Knight, and those made by other physiologists, that the sap descending through the bark, after being modified in the leaves, is the principal cause of the growth of the tree. Thus, if the bark is wounded, the principal formation of new bark is on the upper edge of the wound; and when the wood has been removed, the formation of new wood takes place immediately beneath the bark; and every vessel and passage in the bark and wood of trees seems capable of carrying fluids in different and opposite directions, though more readily and copiously in one direction than in others, which offers something analagous to the anastomosis of vessels in animal bodies. A fact noticed by M. Palisot de Beauvois, is explained on this principle. That gentleman separated different portions of cortical layers from the rest of the bark in several trees, and found that in most instances the separated bark grew in the same manner as the bark in its natural state. The experiment was tried with most success on the lime-tree, the maple, and the lilac. The layers of bark were removed in August, 1810; and in the spring of the next year, in the case of the maple and the lilac, small annual shoots were produced in the parts where the bark was insulated.

The wood of trees is composed of an external part, called *alburnum* or *sap-wood*, and of an internal part, the *heart-wood*. The *alburnum* is white, and full of moisture, and in young trees and annual shoots it reaches even to the pith. The *alburnum* is the great vascular system of the vegetable through which the sap rises, and the vessels in it extend from the leaves to the minutest filaments in the roots.

There is in the *alburnum* a membranous substance, composed of cells, which are constantly filled with the

sap of the plant; and there are in the vascular system several different kinds of tubes; Mirbel has distinguished four species—the *simple tubes*, the *porous tubes*, the *tracheæ*, and the *false tracheæ*.

The tubes, which he has called simple tubes, seem to contain the resinous or oily fluids peculiar to different plants.

The porous tubes likewise contain these fluids; and their use is probably that of conveying them into the sap for the production of new arrangements.

The tracheæ contain fluid matter, which is always thin, watery, and pellucid; and these organs, as well as the false tracheæ, probably carry off water from the denser juices, which are thus enabled to consolidate for the production of new wood.

In the arrangement of the fibres of the wood, there are two distinct appearances. There are series of white and shining laminæ, which shoot from the centre toward the circumference, and these constitute what is called the *silver grain* of the wood.

There are likewise numerous series of concentric layers, which are usually called the *spurious grain*, and their number denotes the age of the tree.*

The silver grain is elastic and contractile; and it has been supposed by Mr. Knight, that the contractions produced in it by changes of temperature are the principal causes of the ascent of the sap.

The silver grain is most distinct in forest trees; but even annual shrubs have a system of fibres similar to it. The analogy of nature is constant and uniform, and similar effects are usually produced by similar organs.

The *pith* occupies the centre of the wood; its texture is membranous; it is composed of cells, which are circular toward the extremity, and hexagonal in

* Fig. 1. represents the section of an elm branch, which exhibits the tubular structure and the silver and spurious grain. Fig. 2. represents the section of part of the branch of an oak. Fig. 3. that of the branch of an ash.

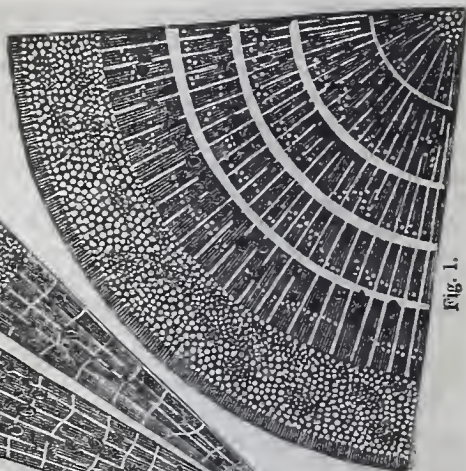


Fig. 1.

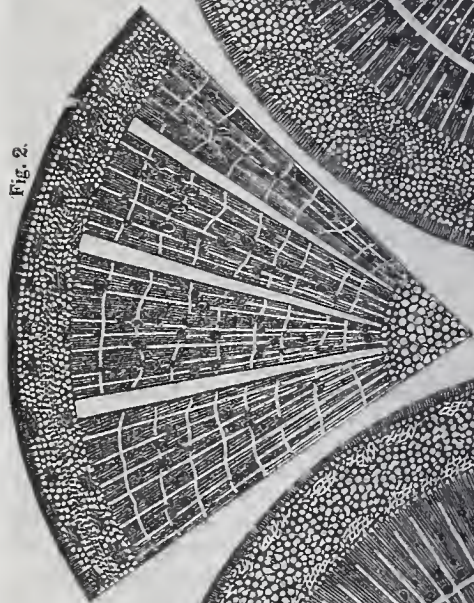


Fig. 2.

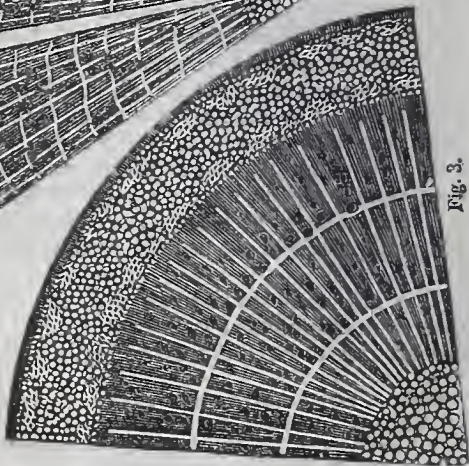


Fig. 3.

the centre of the substance. In the first infancy of the vegetable, the pith occupies but a small space. It gradually dilates, and in annual shoots and young trees offers a considerable diameter. In the more advanced age of the tree, acted on by the heart-wood, pressed by the new layers of the alburnum, it begins to diminish, and in very old forest-trees becomes almost imperceptible.

Many different opinions have prevailed with regard to the use of the pith. Dr. Hales supposed that it was the great cause of the expansion and development of the other parts of the plant; that being the most interior, it was likewise the most acted upon of all the organs, and that from its reaction the phenomena of their development and growth resulted.

Linnæus, whose lively imagination was continually employed in endeavours to discover analogies between the animal and vegetable systems, conceived "that the pith performed for the plant the same functions as the brain and nerves in animated beings." He considered it as the organ of irritability, and the seat of life.

The latest discoveries have proved that these two opinions are equally erroneous. Mr. Knight has removed the pith in several young trees, and they continued to live and to increase.

It is evidently, then, only an organ of secondary importance. In early shoots, in vigorous growth, it is filled with moisture; and it is a reservoir, perhaps, of fluid nourishment at the time it is most wanted. As the heart-wood forms, it is more and more separated from the living part, the alburnum; its functions become extinct, it diminishes, dies, and at last disappears.

The *tendrils*, the *spines*, and other similar parts of plants, are analogous in their organization to the branches, and offer a similar cortical and alburnous organization. It has been shown, by the late observations of Mr. Knight, that the directions of tendrils, and the spiral form they assume, depend upon the un-

equal action of light upon them, and a similar reason has been assigned by M. De Candolle to account for the turning of the parts of plants toward the sun; that ingenious physiologist supposes that the fibres are shortened by the chymical agency of the solar rays upon them, and that, consequently, the parts will move toward the light.*

The *leaves*, the great sources of the permanent beauty of vegetation, though infinitely diversified in their forms, are in all cases similar in interior organization, and perform the same functions.

The alburnum spreads itself from the footstalks into the very extremity of the leaf; it retains its vascular system and its living powers; and its peculiar tubes, particularly the tracheæ, may be distinctly seen in the leaf.

The green membranous substance may be considered as an extension of the parenchyma, and the fine and thin covering as the epidermis. Thus the organization of the roots and branches may be traced into the leaves, which present, however, a more perfect, refined, and minute structure.

One great use of the leaves is for the exposure of the sap to the influence of the air, heat, and light. Their surface is extensive, the tubes and cells very delicate, and their texture porous and transparent.

In the leaves much of the water of the sap is evaporated; it is combined with new principles, and fitted for its organizing functions, and probably passes, in its prepared state, from the extreme tubes of the alburnum into the ramifications of the cortical tubes, and then descends through the bark.

* According to M. De Candolle, in the side of a branch most exposed to light, more carbonic acid is decomposed and more carbon is fixed in its tissue, and consequently it sooner becomes firm and solid than on the other side where least exposed to the agent in question, and therefore the latter elongates in a greater degree than the former. The curvature toward the light is the result. *Vide Physiologie Végétale, par M. De Candolle, p. 832. Paris, 1832.—J. D.*

On the upper surface of leaves, which is exposed to the sun, the epidermis is thick but transparent, and is composed of matter possessed of little organization, which is either principally earthly, or consists of some homogeneous chymical substance. In the grasses it is partly siliceous, in the laurel resinous, and in the maple and thorn it is principally constituted by a substance analogous to wax.

By these arrangements any evaporation, except from the appropriated tubes, is prevented.

On the lower surface the epidermis is a thin transparent membrane full of cavities, and it is probably altogether by this surface that moisture and the principles of the atmosphere necessary to vegetation are absorbed.

If a leaf be turned, so as to present its lower surface to the sun, its fibres will twist so as to bring it as much as possible into its original position; and all leaves elevate themselves on the foot-stalk during their exposure to the solar light, and as it were move toward the sun.

This effect seems, in a great measure, dependant upon the mechanical and chymical agency of light and heat. Bonnet made artificial leaves, which, when a moist sponge was held under the lower surface, and a heated iron above the upper surface, turned exactly in the same manner as the natural leaves. This, however, can be considered only as a very rude imitation of the natural process.

What Linnæus has called the sleep of the leaves, appears to depend wholly upon the suspension of the action of light and heat, and on the operation of moisture.

This singular but constant phenomenon had never been scientifically observed, till the attention of the botanist of Upsal was fortunately directed to it. He was examining particularly a species of lotus, in which four flowers had appeared during the day, and he missed two in the evening; by accurate inspection,

he soon discovered that these two were hidden by the leaves, which had closed round them. Such a circumstance could not be lost upon so acute an observer. He immediately took a lantern, went into his garden, and witnessed a series of curious facts before unknown. All the simple leaves of the plants he examined had an arrangement totally different from their arrangement in the day: and the greater number of them were seen closed or folded together.

The sleep of leaves is, in some cases, capable of being produced artificially. De Candolle made this experiment on the sensitive plant. By confining it in a dark place in the daytime, the leaves soon closed; but on illuminating the chamber with many lamps, they again expanded. So sensible were they to the effects of light and radiant heat.

In the greater number of plants the leaves annually decay, and are reproduced; their decay takes place either at the conclusion of the summer, as in very hot climates, when they are no longer supplied with sap, in consequence of the dryness of the soil, and the evaporating powers of heat; or in the autumn, as in the northern climates at the commencement of the frosts. The leaves preserve their functions, in common cases, no longer than there is a circulation of fluids through them. In the decay of the leaf, the colour assumed seems to depend upon the nature of the chymical change; and as acids are generally developed, it is usually either reddish-brown or yellow; yet there are great varieties. Thus in the oak, it is bright brown; in the beech, orange; in the elm, yellow; in the vine, red; in the sycamore, dark-brown; in the cornel tree, purple; and in the woodbine, blue.

The cause of the preservation of the leaves of evergreens through the winter is not accurately known. From the experiments of Hales, it appears that the force of the sap is much less in plants of this species, and probably there is a certain degree of motion in it, in warm days, even in winter; their juices are less

watery than those of other plants, and probably less liable to be congealed by cold, and certainly not so easy of decomposition; and their vessels are defended by stronger coatings from the action of the elements.

The production of the other parts of the plant takes place at the time the leaves are most vigorously performing their functions. If the leaves are stripped off from a tree in spring, it uniformly dies; and when many of the leaves of forest trees are injured by blasts, or long-continued dryness, the trees always become stag-headed and unhealthy.

The leaves are necessary for the existence of the individual tree; the *flowers* for the continuance of the species. Of all the parts of plants they are the most refined, the most beautiful in their structure, and appear as the master-work of nature in the vegetable kingdom. The elegance of their tints, the variety of their forms, the delicacy of their organization, and the adaptation of their parts, are all calculated to awaken our curiosity, and excite our admiration.

In the flower there are to be observed, first, the *calyx*, or green membranous part forming the support for the coloured floral leaves. This is vascular, and agrees with the common leaf in its texture and organization; it defends, supports, and nourishes the more perfect parts. Second, the *corolla*, which consists either of a single piece, when it is called monopetalous; or of many pieces, when it is called polypetalous. It is usually very vivid in its colours, is filled with an almost infinite variety of small tubes of the porous kind; it encloses and defends the essential parts in the interior, and supplies the juices of the sap to them. These parts are, thirdly, the *stamens* and the *pistils*.

The essential part of the stamens are the summits or *anthers*, which are usually circular and of a highly vascular texture, and covered with a fine dust called the *pollen*.

The pistil is cylindrical, and surmounted by the

style; the top of which is generally round and protuberant.*

In the pistil, when it is examined by the microscope, congeries of spherical forms may usually be perceived, which seem to be the basis of the future seeds.

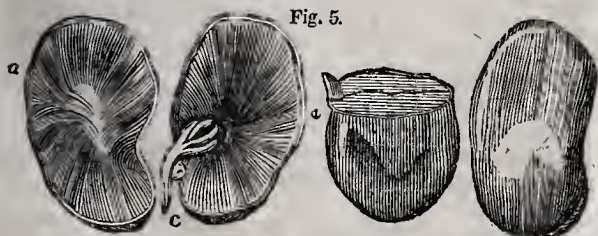
It is upon the arrangement of the stamens and the pistils that the Linnæan classification is founded. The numbers of the stamens and pistils in the same flower, their arrangements, or their division in different flowers, are the circumstances which guided the Swedish philosopher, and enabled him to form a system admirably adapted to assist the memory, and render botany of easy acquisition; and which, though it does not always associate together the plants most analogous to each other in their general characters, is yet so ingeniously contrived as to denote all the analogies of their most essential parts.

The pistil is the organ which contains the rudiments of the seed; but the seed is never formed as a reproductive germe, without the influence of the pollen, or dust on the anthers.

This mysterious impression is necessary to the continued succession of the different vegetable tribes. It is a feature which extends the resemblances of the different orders of beings, and establishes, on a great scale, the beautiful analogy of nature.

The ancients had observed that different date-trees bore different flowers, and that those trees producing flowers which contained pistils bore no fruit, unless in the immediate vicinity of such trees as produced flowers containing stamens. This long-established fact strongly impressed the mind of Malpighi, who ascertained several analogous facts with regard to other vegetables. Grew, however, was the first person who attempted to generalize upon them, and

* Fig 4 represents the common lily; *a* the corolla, *bbbbbb* the anthers, *c* the pistil.



much just reasoning on the subject may be found in his works. Linnæus gave a scientific and distinct form to that which Grew had only generally observed, and has the glory of establishing what has been called the sexual system, upon the basis of minute observations and accurate experiments.

The *seed*, the last production of vigorous vegetation, is wonderfully diversified in form. Being of the highest importance to the resources of nature, it is defended above all other parts of the plant; by soft, pulpy substances, as in the esculent fruits; by thick membranes, as in the leguminous vegetables; and by hard shells, or a thick epidermis, as in the palms and grasses.

In every seed there is to be distinguished, 1. the *organ of nourishment*; 2. the nascent plant, or the *plume*; 3. the nascent root, or the *radicle*.

In the common garden bean, the organ of nourishment is divided into two lobes called *cotyledons*; the plume is the small white point between the upper part of the lobes; and the radicle is the small curved cone at their base.*

In wheat, and in many of the grasses, the organ of nourishment is a single part, and these plants are called *monocotyledonous*. In other cases, it consists of more than two parts, when the plants are called *polycotyledonous*. In the greater number of instances, it is, however, simply divided into two, and is *dicotyledonous*.

The matter of the seed, when examined in its common state, appears dead and inert; it exhibits neither the forms nor the functions of life. But let it be acted upon by moisture, heat, and air, and its organized powers are soon distinctly developed. The cotyledons expand, the membranes burst, the radicle acquires new matter, descends into the soil, and the plume

* Fig 5 (see p. 37) represents the garden bean; *aa* the cotyledons, *b* the plume, *c* the radicle

rises toward the free air. By degrees, the organs of nourishment of dicotyledonous plants become vascular, and are converted into seed leaves, and the perfect plant appears above the soil. Nature has provided the elements of germination on every part of the surface; water, and pure air, and heat, are universally active, and the means for the preservation and multiplication of life are at once simple and grand.

The history of the peculiarities of structure in the different vegetable classes, rather belongs to botanical than agricultural knowledge. As I mentioned in the commencement of this chapter, their organs are possessed of the most distinct analogies, and are governed by the same laws. In the grasses and palms, the cortical layers are larger in proportion than the other parts; but their uses seem to be the same as in forest-trees.

In bulbous roots, the alburnous substance forms the largest part of the vegetable; but in all cases it seems to contain the sap, or solid materials deposited from the sap.

The slender and comparatively dry leaves of the pine and the cedar, perform the same functions as the large and juicy leaves of the fig-tree or the walnut.

Even in the cryptogamia class, where no flowers are distinct, still there is every reason to believe that the production of the seed is effected in the same way as in the more perfect plants. The mosses and lichens, which belong to this family, have no distinct leaves or roots, but they are furnished with filaments which perform the same functions; and even in the fungus and the mushroom there is a system for the absorption and aëration of the sap.

It has been stated that all the different parts of plants are capable of being decomposed into a few elements. Their uses as food, or for the purposes of the arts, depend upon compound arrangements of those elements which are capable of being produced either from their organized parts, or from the juices

they contain; and the examination of the nature of these substances is an essential part of Agricultural Chymistry.

Oils are expressed from the fruits of many plants: resinous fluids from the wood; saccharine matters are afforded by the sap; and dying materials are furnished by leaves, or the petals of flowers: but particular processes are necessary to separate the different compound vegetable substances from each other; such as maceration, infusion, or digestion in water, or in spirits of wine: but the application and the nature of these processes will be better understood when the chymical nature of the substances is known; the consideration of them will therefore be reserved for another place in this chapter.

The compound substances found in vegetables are, 1. gum, or mucilage, and its different modifications; 2. starch; 3. sugar; 4. albumen; 5. gluten; 6. gum-elastic; 7. extract; 8. tannin; 9. indigo; 10. colouring principles; 11. bitter principles; 12. wax; 13. resins; 14. camphor; 15. fixed oils; 16. volatile oils; 17. woody fibre; 18. acids; 19. alkalies, earths, metallic oxydes, and saline compounds.

1. *Gum* is a substance which exudes from certain trees; it appears in the form of a thick fluid, but soon hardens in the air, and becomes solid: when it is white, or yellowish white, more or less transparent, and somewhat brittle, its specific gravity varies from thirteen hundred to fourteen hundred and ninety.

There is a great variety of gums, but the best known are gum arabic, gum senegal, gum tragacanth, and the gum of the plum or cherry tree. Gum is soluble in water, but not soluble in spirits of wine. If a solution of gum be made in water, and spirits of wine or alcohol be added to it, the gum separates in the form of white flakes. Gum can be made to inflame only with difficulty; much moisture is given off in the process, which takes place with a dark smoke and feeble blue flame, and a coal remains.

The characteristic properties of gum are its easy solubility in water, and its insolubility in alcohol.

Mucilage must be considered as a variety of gum; it agrees with it in its most important properties, but seems to have less attraction for water. According to Hermbstadt, when gum and mucilage are dissolved together in water, the mucilage may be separated by means of sulphuric acid. Mucilage may be procured from linseed, from the bulbs of the hyacinth, from the leaves of the marsh-mallows, from several of the lichens, and from many other vegetable substances.

All the varieties of gum and mucilage are nutritious as food. They either partially or wholly lose their solubility in water by being exposed to a heat of 500° or 600° Fahrenheit, but their nutritive powers are not destroyed unless they are decomposed. Gum and mucilage are employed in some of the arts, particularly in calico-printing: till lately, in England, the calico-printers used gum-arabic; but many of them, at the suggestion of Lord Dundonald, now employ the mucilage from lichens.

2. *Starch* is procured from different vegetables, but particularly from wheat or from potatoes. To make starch from wheat, the grain is steeped in cold water till it becomes soft, and yields a milky juice by pressure; it is then put into sacks of linen, and pressed in a vat filled with water: as long as any milky juice exudes the pressure is continued: the fluid gradually becomes clear, and a white powder subsides, which is starch.

Starch is soluble in boiling water, but not in cold water, nor in spirits of wine.* It is a characteristic property of starch to be rendered blue by iodine.

* Exposed to a temperature a little exceeding 212° , it is rendered soluble in cold water, it becomes very similar to gum; is what De Saussure has called amidine, and is best fitted for the use of the calico-printer. Boiling water has an analogous effect on starch; boiled starch, rendered gelatinous, has the properties of amidine.—J. D.

Starch is more readily combustible than gum; when thrown upon red-hot iron, it burns with a kind of explosion, and scarcely any residuum remains.*

Starch forms a principal part of a number of esculent vegetable substances. Sowans, cassava, salop, sago, all of them owe their nutritive powers principally to the starch they contain.

3. *Sugar* in its purest state is prepared from the expressed juice of the *Saccharum officinarum*, or sugarcane: the acid in this juice is neutralized by lime, and the sugar is crystallized by the evaporation of the aqueous parts of the juice, and slow cooling: it is rendered white by the gradual filtration of water through it. In the common process of manufacture, the whitening or refining of sugar is only effected in a great length of time; the water being gradually suffered to percolate through a stratum of clay above the sugar. As the colouring matter of sugar is soluble in a saturated solution of sugar, or sirup, it appears that refining may be much more rapidly and economically performed by the action of sirup on coloured sugar.† The sensible properties of sugar are well known. Its specific gravity according to Fahrenheit is about 1.6. It is soluble in its own weight of water at 50°; it is

* Starch according to the analysis of Gay-Lussac and Thenard, consists of fifteen proportions of carbon, thirteen of oxygen, and twenty-six of hydrogen.

† A French gentleman lately in England stated to the West India planters, that he was in possession of a very expeditious and economical method of purifying and refining sugar, which he was willing to communicate to them for a very great pecuniary compensation. His terms were too high to be acceded to. Conversing on the subject with Sir Joseph Banks, I mentioned to him that I thought it probable that raw sugar might be easily purified by passing sirup through it, which would dissolve the colouring matter. The same idea seems to have occurred about the same time, or before, to the late Edward Howard, Esq., who proved its efficacy experimentally, and some time before his death took out a patent for various improvements in the manufacture of sugar.

likewise soluble in alcohol, but in smaller proportions.

It appears from the experiments of Proust, Achard, Goettling, and Parmentier, that there are many different species of sugar ready formed in the vegetable kingdom. The sugar of the American maple, *Acer saccharinum*, is precisely the same as that of the cane. This sugar is used by the North American farmers, who procure it by a kind of domestic manufacture. The trunk of the tree is bored early in spring, to the depth of about two inches; a wooden spout is introduced into the hole; the juice flows for about five or six weeks. A common-sized tree, that is, a tree from two to three feet in diameter, will yield about two hundred pints of sap, and every forty pints of sap afford about a pound of sugar. The sap is neutralized by lime, and deposits crystals of sugar by evaporation.

The *sugar of grapes* has been lately employed in France as a substitute for colonial sugar. It is procured from the juice of ripe grapes by evaporation and the action of potashes; it is less sweet than common sugar, and its taste is peculiar: it produces a sensation of cold while dissolving in the mouth; and, it is probable, contains a larger portion of water, or its elements.

The roots of the beet (*Beta vulgaris* and *cicla*) afford sugar, by boiling, and the evaporation of the extract: it crystallizes, and does not differ in its properties from the sugar of the cane in France.

Besides the crystallized and solid sugars, there appears to be a sugar which cannot be separated from water, and which exists only in a fluid form; it constitutes a principal part of molasses or treacle; and it is found in a variety of fruits: it is more soluble in alcohol than solid sugar.

The simplest mode of detecting sugar is that recommended by Margraaf. The vegetable is to be boiled in a small quantity of alcohol; solid sugar, if any exist, will separate during the cooling of the solution.

Sugar has been extracted from the following vegetable substances:—

The sap of the birch (*Betula alba*), of the sycamore (*Acer Pseudoplatanus*), of the Bamboo (*Arundo Bambos*), of the maize (*Zea mays*), of the cow parsnip (*Heracleum Spondylium*), of the cocoa-nut tree (*Cocos nucifera*), of the walnut-tree (*Juglans alba*), of the American aloes (*Agave Americana*), of the dulse (*Fucus palmatus*), of the common parsnip (*Pastanica saliva*), of St. John's bread (*Ceratonia Siliqua*); the fruit of the common arbutus (*Arbutus Unedo*), and other sweet-tasted fruits; the roots of the turnip (*Brassica Rapa*), of the carrot (*Daucus Carota*), of parsley (*Apium petroselinum*), the flower of the Euxine rhododendron (*Rhododendron ponticum*), and from the nectarium of most other flowers.

The nutritive properties of sugar are well known. At the time the British market was overstocked with this article from the West India islands, proposals were made for applying it as the food of cattle; experiments had been instituted, which proved that they might be fattened by it: but difficulties connected with the duties laid on sugar prevented the plan from being tried to any extent.

4. *Albumen* is a substance which has only lately been discovered in the vegetable kingdom. It abounds in the juice of the papaw-tree (*Carica papaya*); when the juice is boiled, the albumen falls down in a coagulated state. It is likewise found in mushrooms: and in different species of funguses.

Albumen, in its pure form, is a thick, glairy, tasteless fluid; precisely the same as the white of the egg; it is soluble in cold water; its solution when not too diluted, is coagulated by boiling, and the albumen separates in the form of thin flakes.

According to the experiments of Gay-Lussac and Thernard, albumen is composed of two proportions of azote, five oxygen, nine carbon, thirty-two hydrogen.

The principal part of the almond, and of the ker-

nels of many other nuts, appears from the experiments of Proust, to be a substance analagous to coagulated albumen.

Albumen may be distinguished from other substances by its property of coagulating by the action of heat or acids, when dissolved in water. According to Dr. Bostock, when the solution contains only one grain of albumen to one thousand grains of water, it becomes cloudy by being heated.

Albumen is a substance common to the animal as well as to the vegetable kingdom, and much more abundant in the former.

5. *Gluten* may be obtained from wheaten flour by the following process: the flour is to be made into a paste, which is to be cautiously washed, by kneading it under a small stream of water, till the water has carried off from it all the starch; what remains is gluten. It is a tenacious, ductile, elastic substance. It has no taste. By exposure to air, it becomes of a brown colour. It is very slightly soluble in cold water; but not soluble in alcohol. When a solution of it in water is heated, the gluten separates in the form of yellow flakes; in this respect it agrees with albumen, but differs from it in being infinitely less soluble in water. The solution of albumen does not coagulate when it contains much less than one thousand parts of albumen; but it appears that gluten requires more than one thousand parts of cold water for its solution.

Gluten when burnt affords similar products to albumen, and probably differs very little from it in composition. Gluten is found in a great number of plants: Proust discovered it in acorns, chestnuts, horse-chestnuts, apples, and quinces; barley, rye, peas, and beans; likewise in the leaves of rue, cabbage, cresses, hemlock, borage, saffron, in the berries of the elder, and in the grape. Gluten appears to be one of the most nutritive of the vegetable substances; and wheat seems to owe its superiority to other grain from the circumstance of its containing it in larger quantities.

6. *Gum-elastic* or *caoutchouc*, is procured from the juice of a tree which grows in the Brazils, called *hævea*. When the tree is punctured, a milky juice exudes from it, which gradually deposits a solid substance, and this is gum-elastic.

Gum-elastic is pliable and soft like leather, and becomes softer when heated. In its pure state it is white; its specific gravity is 9335. It is combustible, and burns with a white flame, throwing off a dense smoke, with a very disagreeable smell. It is insoluble in water and in alcohol; it is soluble in ether, volatile oils, and in petroleum, and may be procured from other in an unaltered state, by evaporating its solution in that liquid. Gum-elastic seems to exist in a great variety of plants: among them are, *Jatropha elastica*, *Ficus indica*, *Artocarpus integrifolia*, and *Urceola elastica*.

Bird-lime, a substance which may be procured from the holly, is very analagous to gum-elastic in its properties. Species of the gum-elastic may be obtained from the mistletoe, from gum-mastic, opium, and from the berries of the *Smilax caduca*, in which last plant it has been lately discovered by Dr. Barton.

Gum-elastic, when distilled, affords volatile alkali, water, hydrogen, and carbon, in different combinations. It therefore consists principally of azote, hydrogen, oxygen, and carbon; but the proportions in which they are combined have not yet been ascertained. Gum-elastic is an indigestible substance, not fitted for the food of animals; its uses in the arts are well known.

7. *Extract*, or *the extractive principle*, exists in almost all plants. It may be procured in a state of tolerable purity from saffron, by merely infusing it in water, and evaporating the solution. It may likewise be obtained from catechu, or *Terra japonica*, a substance brought from India. This substance consists principally of astringent matter, and extract; by the action of water upon it, the astringent matter is

first dissolved, and may be separated from the extract. Extract is always more or less coloured: it is less soluble in alcohol and water, but not soluble in ether. It unites with alumina, when that earth is boiled in a solution of extract; and it is precipitated by the salts of alumina, and by many metallic solutions, particularly the solution of muriate of tin.

From the products of its distillation, it seems to be composed principally of hydrogen, oxygen, carbon, and a little azote.

There appears to be almost as many varieties of extract as there are species of plants. The difference of their properties probably in many cases depends upon their being combined with small quantities of other vegetable principles, or to their containing different saline, alkaline, acid, or earthy ingredients. Many dying substances seem to be of the nature of extractive principle; such as the red colouring matter of madder, and the yellow die, procured from weld.

Extract has a strong attraction for the fibres of cotton or linen, and combines with these substances when they are boiled in a solution of it. The combination is made stronger by the intervention of mordants, which are earthy or metallic combinations that unite to the cloth, and enable the colouring matter to adhere more strongly to its fibres.

Extract, in its pure form, cannot be used as an article of food, but it is probably nutritive when united to starch, mucilage, or sugar.

8. *Tannin*, or the tanning principle, may be procured by the action of a small quantity of cold water on bruised grapeseeds, or pounded gallnuts; and by the evaporation of the solution to dryness. It appears as a yellow substance, possessed of a highly astringent taste. It is difficult of combustion. It is very soluble, both in water and alcohol, but insoluble in ether. When a solution of glue, or isingglass, (*gelatine*,) is mixed with an aqueous solution of tannin, the two substances, that is, the animal and vegetable

matters, fall down in combination, and form an insoluble precipitate.

When tannin is distilled in close vessels, the principal products are charcoal, carbonic acid, and inflammable gases, with a minute quantity of volatile alkali. Hence its elements seem the same as those of extract, but probably in different proportions. The characteristic property of tannin is its action upon solutions of isingglass or gelly; this particularly distinguishes it from extract, with which it agrees in most other chymical qualities.

There are many varieties of tannin, which probably owe the difference of their properties to combinations with other principles, especially extract, from which it is not easy to free tannin. The purest species of tannin is that obtained from the seeds of the grape; this forms a white precipitate, with solution of isingglass. The tannin from gallnuts resembles it in its properties. That from sumach affords a yellow precipitate; that from kino a rose-coloured; that from catechu, a fawn-coloured one. The colouring matter of Brazil-wood, which M. Chevreul considers as a peculiar principle, and which he has called *Hematine*, differs from other species of tannin, in affording a precipitate with gelatine, which is soluble in abundance of hot water. Its taste is much sweeter than that of the other varieties of tannin, and it may perhaps be regarded as a substance intermediate between tannin and extract.

Tannin is not a nutritive substance, but is of great importance in its application to the art of tanning. Skin consists almost entirely of gelly or *gelatine*, in an organized state, and is soluble by the long-continued action of boiling water. When skin is exposed to solutions containing tannin, it slowly combines with that principle; its fibrous texture and coherence are preserved; it is rendered perfectly insoluble in water, and is no longer liable to putrefaction: in short, it becomes a substance in chymical composi-

tion precisely analogous to that furnished by the solution of gelly and the solution of tannin.

In general, in England, the bark of the oak is used for affording tannin in the manufacture of leather: but the barks of some other trees, particularly the Spanish chestnut, have lately come into use. The following table will give a general idea of the relative value of different species of barks. It is founded on the result of experiments made by myself.

Table of numbers exhibiting the quantity of tannin afforded by 480 lbs. of different barks, which express nearly their relative values.

Average of entire bark of middle-sized Oak, cut			
		in spring	29
"	"	of Spanish Chestnut	21
"	"	of Leicester willow, large	
		size	33
"	"	of Elm	13
"	"	of Common Willow, large	11
"	"	of Ash	16
"	"	of Beech	10
"	"	of Horse-Chestnut	9
"	"	of Sycamore	11
"	"	of Lombardy Poplar	15
"	"	of Birch	8
"	"	of Hazel	14
"	"	of Black Thorn	16
"	"	of Coppice Oak	32
"	"	of Oak, cut in autumn	21
"	"	of Larch, cut in autumn	8
White interior corticle layers of Oak Bark			72

The quantity of the tannin principle in barks differs in different seasons; when the spring has been very cold the quantity is smallest. On an average, four or five pounds of good oak bark are required to form one pound of leather. The inner cortical layers in all barks contain the largest quantity of tannin. Barks

contain the greatest proportion of tannin at the time the buds begin to open—the smallest quantity in winter.

The extractive or colouring matters found in barks, or in substances used in tanning, influence the quality of leather. Thus skin tanned with gallnuts is much paler than skin tanned with oak bark, which contains a brown extractive matter. Leather made from catechu is of a reddish tint. It is probable that in the process of tanning, the matter of skin and the tanning principle first enter into union, and that the leather, at the moment of its formation, unites to the extractive matter.

In general, skins in being converted into leather increase in weight about one third,* and the operation is most perfect when they are tanned slowly. When skins are introduced into very strong infusions of tannin, the exterior parts immediately combine with that principle, and defend the interior parts from the action of the solution: such leather is liable to crack and to decay by the action of water.

Besides the barks already mentioned, there are a number of others which contain the tanning principle. Few barks, indeed, are entirely free from it. It is likewise found in the wood and leaves of a number of trees and shrubs, and is one of the most generally diffused of the vegetable principles.

9. *Indigo* may be procured from wood (*Isatis tinctoria*), by digesting alcohol on it, and evaporating the solution. White crystalline grains are obtained, which gradually become blue by the action of the atmosphere: these grains are the substance in question.

The indigo of commerce is principally brought from America.† It is procured from the *Indigofera argentea*, or wild indigo, the *Indigofera disperma*, or Gua-

* This estimation must be considered as applying to *dry* skin and *dry* leather.

† The largest quantity is now procured from the East Indies.

timala indigo, and the *Indigofera tinctoria*, or French indigo. It is prepared by fermenting the leaves of those trees in water. Indigo, in its common form, appears as a fine deep blue powder. It is insoluble in water, and but slightly soluble in alcohol: its true solvent is sulphuric acid: eight parts of sulphuric acid dissolve one part of indigo; and the solution diluted with water forms a very fine blue dye.

Indigo is one of the most valuable and most extensively used of the dyeing materials.

10. There are a number of colouring principles found in different vegetable productions, the properties of which are less marked than those of indigo, and the separation more difficult. The colouring matters of carthamus and madder are the most fixed among the red vegetable colours. A number of vegetable substances are rendered red by the action of acids, and green by that of alkalies. They all seem to be composed of different proportions of hydrogen, oxygen, and carbon; but are so liable to change, that few distinct experiments have been made upon their nature.

11. The *bitter principle* is very extensively diffused in the vegetable kingdom; it is found abundantly in the hop (*Humulus Lupulus*), in the common broom (*Spartium scoparium*), in the chamomile (*Anthemis nobilis*), and in *Quassia amara* and *excelsa*. It is obtained from those substances by the action of water or alcohol, and evaporation. It is usually of pale yellow colour; its taste is intensely bitter. It is very soluble, both in water and alcohol; and has little or no action on alkaline, acid, saline, or metallic solution.

The natural bitter principle is of great importance in the art of brewing; it checks fermentation, and preserves fermented liquors; it is likewise used in medicine.

The bitter principle, like the narcotic principle, appears to consist principally of carbon, hydrogen, and oxygen, with a little azote.

12. *Wax* is found in a number of vegetables; it is

procured in abundance from the berries of the wax myrtle (*Myrica cerifera*): it may be likewise obtained from the leaves of many trees: in its pure state it is white. Its specific gravity is nine thousand six hundred and sixty-two; it melts at one hundred and fifty-five degrees: it is dissolved by boiling alcohol: but it is not acted upon by cold alcohol: it is insoluble in water: its properties as a combustible body are well known.

The wax of the vegetable kingdom seems to be precisely of the same nature as that afforded by the bee.

From the experiments of MM. Gay-Lussac and Thenard, it appears that wax consists of very nearly thirty-seven proportions of hydrogen, twenty-one of charcoal, and one of oxygen.

13. *Resin* is very common in the vegetable kingdom. One of the most usual species is that afforded by the different kinds of fir. When a portion of the bark is removed from a fir-tree in spring, a matter exudes, which is called turpentine; by heating this turpentine gently, a volatile oil rises from it, and a more fixed substance remains: this substance is resin.

The resin of the fir is the substance commonly known by the name of rosin; its properties are well known. Its specific gravity is 1072. It melts readily, burns with a yellow light, throwing off much smoke. Resin is insoluble in water, either hot or cold; but very soluble in alcohol. When a solution of resin in alcohol is mixed with water, the solution becomes milky; the resin is deposited by the stronger attraction of the water for the alcohol.

Resins are obtained from many other species of trees. *Mastich* from the *Pistacia Lentiscus*, *elemi* from the *Amyris elemifera*, *copal* from the *Rhus copallinum*, *sandarach* from the common juniper. Of these resins copal is the most peculiar. It is the most difficultly dissolved in alcohol; and for this purpose must be exposed to that substance in vapour; or the alcohol

employed must hold camphor in solution. According to Gay-Lussac and Thenard, resin consists of eight proportions of carbon, twelve of hydrogen, and one of oxygen.

Resins are used for a variety of purposes. Tar and pitch principally consist of resin, in a partially decomposed state. Tar is made by the slow combustion of the fir; and pitch by the evaporation of the more volatile parts of tar. Resins are employed as varnishers, and for these purposes are dissolved in alcohol or oils. Copal forms one of the finest. It may be made by boiling it in powder with oil of rosemary, and then adding alcohol to the solution.

14. *Camphor* is produced by distilling the wood of the camphor-tree (*Laurus Camphora*), which grows in Japan. It is a very volatile body, and may be purified by distillation. Camphor is a white, brittle, semitransparent substance, having a peculiar odour, and a strong acrid taste. It is very slightly soluble in water; more than one hundred thousand parts of water are required to dissolve one part of camphor. It is very soluble in alcohol; and by adding water in small quantities at a time to the solution of camphor in alcohol, the camphor separates in a crystallized form. It is soluble in nitric acid, and is separated from it by water.

Camphor is very inflammable; it burns with a bright flame, and throws off a great quantity of carbonaceous matter. It forms, in combustion, water, carbonic acid, and a peculiar acid called *camphoric acid*. No accurate analysis has been made of camphor, but it seems to approach to the resins in its composition; and consists of carbon, hydrogen, and oxygen.

Camphor exists in other plants besides the *Laurus Camphora*. It is procured from species of the *Laurus* growing in Sumatra, Borneo, and other of the East Indian isles. It has been obtained from thyme (*Thymus Serpillum*), marjoram (*Origanum Majorana*),

ginger-tree (*Amomum Zingiber*), sage (*Salvia officinalis*). Many volatile oils yield camphor by being merely exposed to the air.

15. *Fixed oil* is obtained by expression from seeds and fruits; the olive, the almond, linseed, and rape-seed, afford the most common vegetable fixed oils. The properties of fixed oils are well known. Their specific gravity is less than that of water; that of olive and of rape-seed oil is .913; that of linseed and almond oil .932; that of palm oil .968; that of walnut and beach-mast oil .923. Many of the fixed oils congeal at a lower temperature than that at which water freezes. They all require for their evaporation a higher temperature than that at which water boils. The products of the combustion of oil are water and carbonic acid gas.

The following is a list of fixed oils, and of the trees that afford them:—

Olive oil, from the olive-tree (*Olea europea*), linseed oil, from the common and perennial flax (*Linum usitatissimum et perenne*), nut oil, from the hazelnut (*Corylus Avellana*), walnut (*Juglans regia*), hemp oil, from the hemp (*Cannabis sativa*), almond oil, from the sweet almond (*Amygdalus communis*), beech oil, from the common beech (*Fagus sylvatica*), rape-seed oil, from the rapeseeds (*Brassica Napus et campestris*), poppy oil, from the poppy (*Papaver somniferum*), oil of sesamum, from the sesamum (*Sesamum orientale*), cucumber oil, from the gourds (*Cucurbita Pepo et Melopepo*), oil of mustard, from the mustard (*Sinapis nigra et arvensis*), oil of sunflower, from the annual and perennial sunflower (*Helianthus annuus et perennis*), castor oil, from the palmi christi (*Ricinus communis*), tobacco-seed oil, from the tobacco (*Nicotiana Tabacum et rustica*), plum-kernel oil, from the plum-tree (*Prunus domestica*), grape-seed oil, from the vine (*Vitis vinifera*), butter of cocoa, from the cocoa-tree (*Theobroma Cacao*), Laurel oil, from the sweet bay tree (*Laurus nobilis*).

The fixed oils are very nutritive substances; they are of great importance in their applications to the purposes of life. Fixed oil, in combination with soda, forms the finest kind of hard soap. The fixed oils are used extensively in the mechanical arts, and for the preparation of pigments and varnishes.

16. *Volatile oil*, likewise called *essential oil*, differs from fixed oil, in being capable of evaporation by a much lower degree of heat, in being soluble in alcohol, and in possessing a very slight degree of solubility in water.

There is a great number of volatile oils, distinguished by their smell, their taste, their specific gravity, and other sensible qualities. A strong and peculiar odour may, however, be considered as the great characteristic of each species: the volatile oils inflame with more facility than the fixed oils, and afford, by their combustion, different proportions of the same substances, water, carbonic acid, and carbon.

The peculiar odours of plants seem, in almost all cases, to depend upon the peculiar volatile oils they contain. All the perfumed distilled waters owe their peculiar properties to the volatile oils they hold in solution. By collecting the aromatic oils, the fragrance of flowers, so fugitive in the common course of nature, is as it were imbodied and made permanent.

It cannot be doubted that the volatile oils consist of carbon, hydrogen, and oxygen; but no accurate experiments have as yet been made on the proportions in which these elements are combined.

The volatile oils have never been used as articles of food; many of them are employed in the arts, in the manufacture of pigments and varnishes; but their most extensive application is as perfumes.

17. *Woody fibre* is procured from wood, bark, leaves, or flowers of trees, by exposing them to the repeated action of boiling water and boiling alcohol. It is the insoluble matter that remains, and is the basis of the solid organized parts of plants. There are as many

varieties of woody fibre as there are plants and organs of plants; but they are all distinguished by their fibrous texture and their insolubility.

Woody fibre burns with a yellow flame, and produces water and carbonic acid in burning. When it is distilled in close vessels, it yields a considerable residuum of charcoal. It is from woody fibre, indeed, that charcoal is procured for the purposes of life.

The following table contains the results of experiments made by Mr. Mushet, on the quantity of charcoal afforded by different wood:—

100 parts of	Lignum Vitæ	.	26.8	of charcoal
"	"		25.4	"
"	"		24.5	"
"	"		23.2	"
"	"		22.6	"
"	"		21.4	"
"	"		20.6	"
"	"		19.9	"
"	"		19.9	"
"	"		19.9	"
"	"		19.5	"
"	"		19.2	"
"	"		18.4	"
"	"		17.9	"
"	"		17.4	"
"	"		16.4	"

It will be unnecessary to speak of the applications of woody fibre. The different uses of the woods, cotton, linen, the barks of trees, are sufficiently known. Woody fibre appears to be an indigestible substance.

18. The acids found in the vegetable kingdom are numerous; the true vegetable acids which exist ready formed in the juices or organs of plants, are the *oxalic, citric, tartaric, benzoic, acetic, meconic, malic, gallic, and prussic acid*.

All these acids, except the acetic, malic, and prussic acids, are white crystallized bodies. The acetic, malic, and prussic acids have been obtained only in

the fluid state; they are all more or less soluble in water; all have a sour taste except the gallic and prussic acids; of which the first has an astringent taste, and the latter a taste like that of bitter almonds. The meconic acid exists in opium.

The oxalic acid exists, uncombined, in the liquor which exudes from the chich pea (*Cicer arietinum*), and may be procured from wood sorrel (*Oxalis Acetosella*), common sorrel, and other species of *Rumex*: and from the *Geranium acidum*. Oxalic acid is easily discovered and distinguished from other acids by its property of decomposing all calcareous salts, and forming with lime a salt insoluble in water; and by its crystallizing in four-sided prisms.

The citric acid is the peculiar acid existing in the juice of lemons and oranges. It may likewise be obtained from the cranberry, whortleberry, and hip.

Citric acid is distinguished by its forming a salt insoluble in water with lime; but decomposable by the mineral acids.

The tartaric acid may be obtained from the juice of mulberries and grapes; and likewise from the pulp of the tamarind. It is characterized by its property of forming a difficultly soluble salt with potassa, and an insoluble salt decomposable by the mineral acids with lime.

Benzoic acid may be procured from several resinous substances by distillation; from benzoin, storax, and balsam of Tolu. It is distinguished from the other acids by its aromatic odour, and by its extreme volatility.

Malic acid may be obtained from the juice of apples, barberries, plums, elderberries, currants, strawberries, and raspberries. It forms a soluble salt with lime; and is easily distinguished by this test from the acids already named.

Acetic acid, or vinegar, may be obtained from the sap of different trees. It is distinguished from malic acid by its peculiar odour; and from the other vege-

table acids by forming soluble salts with the alkalies and earths.

Gallic acid may be obtained by gently and gradually heating powdered gallnuts, and receiving the volatile matter in a cool vessel. A number of white crystals will appear, which are distinguished by their property of rendering solutions of iron deep purple.

The vegetable prussic acid is procured by distilling laurel leaves, or the kernels of the peach, or cherry, or bitter almonds. It is characterized by its property of forming a bluish green precipitate, when a little alkali is added to it, and it is poured into solutions containing iron. It is very analogous in its properties to the prussic acid obtained from animal substances; or by passing ammonia over heated charcoal; but this last body forms with the red oxyde of iron, the deep bright blue substance called Prussian blue.

The applications of the vegetable acids are well known. The acetic and citric acids are extensively used. The agreeable taste and wholesomeness of various vegetable substances used as food, materially depend upon the vegetable acid they contain.

19. It is uncertain whether ammonia or the volatile alkali exists ready formed in plants: but it is evolved from many of them by the action of lime or fixed alkali, assisted by a gentle heat; though it may be always imagined to be generated during the process by the combination of azote and carbon. The ingenious researches of M. Serturmer, followed by those of other chymists, have made us acquainted with the alkaline properties of several compound vegetable substances, which were not suspected to belong to this class of bodies, such as morphina, strychnina, brucina, picrotoxina, delphina.* These compounds, which are found respectively in opium, nux vomica, Brucea anti-dysenterica, cocculus indicus, and Delphinium Staphi-

* Many more have since been discovered, as codeia, narceia, aricina, &c. All the compounds of this class are composed of carbon, hydrogen, azote, and oxygen.

sagria, agree with alkalies in their effects upon vegetable colours, and in combining with acids, into peculiar neutrosaline compounds. They form the narcotic or poisonous principles of the plants in which they are found, and probably many more of them will be discovered. They are not very interesting to the agriculturist, except in this point of view, *that possibly many noxious vegetable substances may be rendered useful as the food of cattle*, by extracting their noxious principles by means of acids; and this is a subject well worthy of experimental investigation.

Fixed alkali may be obtained in aqueous solution from most plants by burning them, and treating the ashes with quick-lime and water. The vegetable alkali, or potassa, is the common alkali in the vegetable kingdom. This substance, in its pure state, is white and semi-transparent, requiring a strong heat for its fusion, and possessed of a highly caustic taste. In the matter usually called pure potassa by chymists, it exists, combined with water; and in that commonly called pearlashes, or potashes in commerce, it is combined with a small quantity of carbonic acid. Potassa, in its uncombined state, consists of the highly-inflammable metal potassium and oxygen, one proportion of each.

Soda, or the mineral alkali, is found in some plants that grow near the sea; and is obtained combined with water, or carbonic acid, in the same manner as potassa; and consists of one proportion of sodium, and two proportions of oxygen. In its properties, it is very similar to potassa; but it may be easily distinguished from it by this character—it forms a hard soap with oil; potassa forms a soft soap.

Pearlashes, and barilla and kelp, or the impure soda obtained from the ashes of marine plants, are very valuable in commerce, principally on account of their uses in the manufacture of glass and soap. Glass is made from fixed alkali, flint, and certain metallic substances.

To know whether a vegetable yields alkali, it should be burnt, and the ashes washed with a small quantity of water. If the water, after being for some time exposed to the air, reddens paper tinged with turmeric, or renders vegetable blues green, it contains alkali.

To ascertain the relative quantities of potashes afforded by different plants, equal weights of them should be burnt; the ashes washed in twice their volume of water: the washings should be passed through blotting-paper, and evaporated to dryness. The relative weights of the salt obtained will indicate very nearly the relative quantities of alkali they contain.

The value of marine plants in producing soda may be estimated in the same manner, with sufficient correctness for all commercial purposes.

Herbs, in general, furnish four or five times, and shrubs two or three times, as much potashes as trees. The leaves produce more than the branches, and the branches more than the trunk. Vegetables burnt in a green state produce more ashes than in a dry state.

The following table contains a statement of the quantity of potashes afforded by some common trees and plants:—

10,000 parts of	Oak	.	.	.	15
"	"	Elm	.	.	39
"	"	Beech	.	.	12
"	"	Vine	,	.	55
"	"	Poplar	.	.	7
"	"	Thistle	.	.	53
"	"	Fern	.	.	62
"	"	Cow Thistle	.	.	196
"	"	Wormwood	.	.	730
"	"	Vetches	.	.	275
"	"	Beans	.	.	200
"	"	Fumitory	.	.	760

The earths found in plants are four; silica, or the earth of flints; alumina, or pure clay; lime, and magnesia. They are procured by incineration. The

lime is usually combined with carbonic acid. This substance and silica are much more common in the vegetable kingdom than magnesia, and magnesia more common than alumina. The earths form a principal part of the matter insoluble in water, afforded by the ashes of plants. The silica is known by not being dissolved by acids; the calcareous earth, unless the ashes have been very intensely ignited, dissolves with effervescence in muriatic acid. Magnesia forms a soluble and crystallizable salt, and lime a difficultly soluble one with sulphuric acid. Alumina is distinguished from the other earths, by being acted upon very slowly by acids; and in forming salts very soluble in water, and difficult of crystallization with them.

The earths appear to be compounds of certain peculiar metals, and oxygen, one proportion of each.

The earths afforded by plants are applied to no uses of common life; and there are few cases in which the knowledge of their nature can be of importance, or afford interest to the farmer.

The only *metallic oxydes* found in plants, are those of iron and manganese: they are detected in the ashes of plants; but in very minute quantities only. When the ashes of plants are reddish brown, they abound in oxydes of iron; when black or purple, in oxyde of manganese; when these colours are mixed, they contain both substances.

The saline compounds contained in plants, or afforded by their incineration, are very various. The sulphuric acid combined with potassa, or sulphate of potassa, is one of the most usual. Common salt is likewise very often found in the ashes of plants; likewise phosphate of lime, which is insoluble in water, but soluble in muriatic acid. Compounds of the nitric, muriatic, sulphuric, and phosphoric acids, with alkalis and earths, exist in the sap of many plants, or are afforded by their evaporation and incineration. The salts of potassa are distinguished from those of

soda by their producing a precipitate in solutions of platina: those of lime are characterized by the cloudiness they occasion in solutions containing oxalic acid; those of magnesia, by being rendered cloudy by solutions of ammonia. Sulphuric acid is detected in salts, by the dense white precipitate it forms in solutions of baryta. Muriatic acid, by the cloudiness it communicates to solution of nitrate of silver; and when salts contain nitric acid, they produce scintillations by being thrown upon burning coals.

The most essential vegetable substances consist of hydrogen, carbon, and oxygen in different proportions, generally alone, but in some few cases combined with azote. The acids, alkalies, earths, metallic oxydes, and saline compounds, though necessary in the vegetable economy, must be considered as of less importance, particularly in their relation to agriculture, than the other principles; and as it appears from M. de Saussure's, and from other experiments, they differ in the same species of vegetable when it is raised on different soils.

MM. Gay-Lussac and Thenard have deduced three propositions, which they have called *laws*, from their experiments on vegetable substances. *The first* is, "That a vegetable substance is always acid whenever the oxygen it contains is to the hydrogen in a greater proportion than in water."

The third, "That a vegetable substance is neither acid nor resinous, but is either saccharine or mucilaginous, or analogous to woody fibre or starch, whenever the oxygen and hydrogen in it are in the same proportions as in water."

The second, "That a vegetable substance is always resinous, or oily or spirituous, whenever it contains oxygen in a smaller proportion to the hydrogen than exists in water."

New experiments upon other vegetable substances, besides those examined by MM. Gay-Lussac and Thenard, are required before these interesting conclu-

sions can be fully admitted. Their researches establish, however, the close analogy between several vegetable compounds differing in their sensible qualities, and combined with those of other chymists, offer simple explanations of several processes in nature and art, by which different vegetable substances are converted into each other, or changed into new compounds.

Gum and sugar, excluding the different proportions of water they may contain, afford nearly the same elements by analysis; and starch differs from them only in containing a little more carbon. The peculiar properties of gum and sugar must depend chiefly upon the different arrangement, or degree of condensation of their elements; and it would be natural to conceive, from the composition of these bodies, as well as that of starch, that all three would be easily convertible one into the other; which is actually the case.

At the time of the ripening of corn, the saccharine matter in the grain, and that carried from the sap vessels into the grain, become coagulated, probably simply by losing water, and form starch. And in the process of malting, the converse change occurs. The starch of grain is converted into sugar. As there is a little absorption of oxygen, and a formation of carbonic acid in this case, it is likely that the starch loses a little carbon, which combines with the oxygen to form carbonic acid; and probably the oxygen tends to acidify the gluten of the grain, and thus breaks down the texture of the starch; gives a new arrangement to its elements, and renders it soluble in water.

Mr. Cruikshank, by exposing sirup to a substance named phosphuret of lime, which has a great tendency to decompose water, converted a part of the sugar into a matter analogous to mucilage. And M. Kirchhoff, recently, has converted starch into sugar by a very simple process, that of boiling in very diluted

sulphuric acid.* The proportions are one hundred parts of starch, four hundred parts of water, and one part of sulphuric acid by weight. This mixture is to be kept boiling for forty hours; the loss of water by evaporation being supplied by new quantities. The acid is to be neutralized by lime; and the sugar crystallized by cooling. This experiment has been tried with success by many persons. Sir C. Tuthill, from a pound and a half of potato-starch, procured a pound and a quarter of crystalline, brown sugar; which he conceives possessed properties intermediate between cane-sugar, and grape-sugar.

It is probable, from the experiments of M. Theodore de Saussure, that the conversion of starch into sugar, in this experiment, is effected merely by its combination with water; for his experiments prove that the acid is not decomposed, and that no elastic matter is set free, and that the sugar weighs more than the starch from which it is formed: probably the colour of the sugar, is owing to the disengagement, or new combination of a little carbon, the slight excess of which, as has been just stated, constitutes the only difference (independent of the different quantities of water they may contain) perceptible by analysis between sugar and starch.

M. Bouillon la Grange, by slightly roasting starch, has rendered it soluble in cold water; and the solution evaporated afforded a substance, having the characters of mucilage. And by experiments similar to those of M. Kirchhoff, M. Braconnot has lately shown that saccharine and mucilaginous substances may be procured from various forms of woody fibre; and I

* Some kinds of vinegar, especially those made from sugar, are converted into an insoluble substance resembling lignin, or the principle of the woody fibre, by exposure to the atmosphere. This I have witnessed in many instances; the new substance, which is like lignin, forms on the surface of the vinegar, and leaves a strong dense crust, occasionally in appearance not unlike the buffy coat of blood.—*J. D.*

have seen specimens of soft sugar made from linen rags.

Gluten and albumen differ from the other vegetable products, principally by containing azote. When gluten is kept long in water, it undergoes fermentation; ammonia (which contains its azote) is given off with acetic acid; and a fatty matter and a substance analogous to woody fibre remain.

Extract, tannin, and gallic acid, when their solutions are long exposed to air, deposite a matter similar to woody fibre; and the solid substances are rendered analogous to woody fibre, by slight roasting; and in these cases it is probably that part of their oxygen and hydrogen is separated as water.

All the other vegetable principles differ from the vegetable acids in containing more hydrogen and carbon, or less oxygen; many of them, therefore, are easily converted into vegetable acids by a mere subtraction of some proportions of hydrogen. The vegetable acids, for the most part, are convertible into each other by easy processes. The oxalic contains most oxygen; the acetic the least: and this last substance is easily formed by the distillation of other vegetable substances, or by the action of the atmosphere on such of them as are soluble in water; probably by the mere combination of oxygen with hydrogen and carbon, or in some cases by the subtraction of a portion of hydrogen.

The arrangement of many of the vegetable principles in the different parts of plants has been incidentally mentioned in this chapter; but a more particular statement is required to afford just views of the relation between their organization and chymical constitution, which is an object of great importance. The tubes and hexagonal cells in the vascular system of plants are composed of woody fibre; and when they are not filled with fluid matter they contain some of the solid materials which formed a constituent part of the fluids belonging to them.

In the roots, trunk, and branches, the bark, alburnum, and heart-wood, the leaves and flowers, the great basis of the solid parts is woody fibre. It forms by far the greatest part of the heart-wood and bark; there is less in the alburnum, and still less in the leaves and flowers. The alburnum of the birch contains so much sugar and mucilage, that it is sometimes used in the north of Europe as a substitute for bread. The leaves of the cabbage, broccoli, and seacale, contain much mucilage, a little saccharine matter, and a little albumen. From one thousand parts of the leaves of common cabbage I obtained forty-one parts of mucilage, twenty-four of sugar, and eight of albuminous matter.

In bulbous roots, and sometimes in common roots, a large quantity of starch, albumen, and mucilage are often found deposited in the vessels; and they are most abundant after the sap has ceased to flow; and afford a nourishment for the early shoots made in spring. The potato is the bulb that contains the largest quantity of soluble matter in its cells and vessels; and it is of most importance in its application as food. Potatoes in general afford from one fifth to one seventh their weight of dry starch. From one hundred parts of the common *kidney potato*, Dr. Pearson obtained from thirty-two to twenty-eight parts of meal, which contained from twenty-three to twenty of starch and mucilage: and one hundred parts of the *apple potato* in various experiments, afforded me from eighteen to twenty parts of pure starch. From five pounds of the variety of the potato called *captain hart*, Mr. Skrimshire, jun., obtained twelve ounces of starch, from the same quantity of the *rough red* potato ten and a half ounces, from the *moulton white* eleven and three fourths ounces, from the *Yorkshire kidney* ten and three fourths ounces, from *hundred eyes* nine ounces, from *purple red* eight and a half ounces, from *ox noble* eight and one fourth. The other soluble substances in the potato are albumen and mucilage.

From the analysis of Einhoff it appears that 7680 parts of potato afford:—

Of Starch	1153
“ Fibrous matter analogous to starch	540
“ Albumen	107
“ Mucilage in the state of a saturated solution	312
	2122

So that a fourth part of the weight of the potato at least may be considered as nutritive matter. Mr. Knight informs me, that he has found the best potatoes, such as the Irish apple, to possess much greater specific gravity than the inferior varieties; the specific gravity varying from one thousand and seventy-five to eleven hundred, and it is probable that their nutritive properties are nearly proportionate to their specific gravities.

The turnip, carrot, and parsnip, afford principally saccharine, mucilaginous, and extractive matter. I obtained from one thousand parts of common turnips seven parts of mucilage, thirty-four of saccharine matter, and nearly one part of albumen. One thousand parts of carrots furnished ninety-five parts of sugar, three parts of mucilage, and half a part of extract; one thousand parts of parsnip afforded ninety parts of saccharine matter, and nine parts of mucilage. The *Walcheren* or *white carrot*, gave, in one thousand parts, ninety-eight parts of sugar, two parts of mucilage, and one of extract.

Fruits, in the organization of their soft parts, approach to the nature of bulbs. They contain a certain quantity of nourishment laid up in their cells for the use of the embryo plant; mucilage, sugar, starch, are found in many of them often combined with vegetable acids. Most of the fruit-trees common in Britain have been naturalized on account of the saccharine matter they contain, which, united to the vegetable

acids and mucilage, renders them at once agreeable to the taste, and nutritive.

The value of fruits for the manufacture of fermented liquors may be judged of from the specific gravity of their expressed juices; but the quantity of juice and the consistence of the pulp differ widely in different species of fruits, and therefore the specific gravity of the fruit will not always indicate the value of its fermented produce. The best cider and perry are made from those apples and pears that afford the densest juices; and a comparison between different fruits may be made with tolerable accuracy by plunging them together into a saturated solution of salt, or a strong solution of sugar; those that sink deepest will afford the richest juice.*

Starch or coagulated mucilage forms the greatest part of the seeds and grains used for food; and they are generally combined with gluten, oil, or albuminous matter. In corn, with gluten; in peas and beans, with albuminous matter; and in rapeseed, hempseed, linseed, and the kernels of most nuts, with oils.

I found 100 parts of good full-grained wheat sown in autumn, to afford:—

	Of Starch	77
	“ Gluten	19
100 parts of wheat sown in spring,		
	Of Starch	70
	“ Gluten	24
100 parts of Barbary wheat,		
	Of Starch	74
	“ Gluten	23
100 parts of Sicilian wheat,		
	Of Starch	75
	“ Gluten	21

* The specific gravity of the expressed juice of the water-melon, the most succulent of fruits, exceeds very little that of distilled water. One specimen of watermelon, which I examined in Malta, yielded ninety-seven parts of water, and three of solid matter, principally saccharine and mucilaginous.—*J. D.*

I have examined different specimens of North American wheat; all of them have contained rather more gluten than the British. In general, the wheat of warm climates abound more in gluten, and in insoluble parts; and it is of greater specific gravity, harder, and more difficult to grind.

The wheat of the south of Europe, in consequence of the larger quantity of gluten it contains, is peculiarly fitted for making maccaroni, and other preparations of flour, in which a glutinous quality is considered as an excellence.

In some experiments made on barley, I obtained from 100 parts of full and fair Norfolk barley:—

Of Starch	79
“ Gluten	6
“ Husk	8

The remaining seven parts saccharine matter. The sugar in barley is probably the chief cause why it is more proper for malting than any other species of grain.

Einhoff has published a minute analysis of barley meal. He found in 3840 parts:—

Of volatile matter	360
“ Albumen	44
“ Saccharine matter	200
“ Mucilage	176
“ Phosphate of lime, with some albumen	9
“ Gluten	135
“ Husk, with some gluten and starch	260
“ Starch not quite free from gluten .	2580
“ Loss	78

Rye afforded to Einhoff, in 3840 parts, 2520 meal, 930 husk, and 390 moisture; and the same quantity of meal analyzed gave:—

Of Starch	2345
“ Albumen	116
“ Mucilage	426
“ Saccharine matter	126
“ Gluten not dried	364

Remainder husk and loss.

I obtained from one thousand parts of rye, grown in Suffolk, sixty-one parts of starch, and five parts of gluten.

One hundred parts of oats, from Sussex, afforded me fifty-nine parts of starch, six parts of gluten, and two of saccharine matter.

One thousand parts of peas, grown in Norfolk, afforded me five hundred and one parts of starch, twenty-two parts of saccharine matter, thirty-five parts of albuminous matter, and sixteen parts of extract, which became insoluble during the evaporation of the saccharine fluid.

From 3840 parts of marsh beans (*Vicia faba*), Einhoff obtained :—

Of Starch	1312
“ Albumen	31
“ other matters which may be con- ceived nutritive; such as gummy, starchy, fibrous matter analogous to animal matter	1204

The same quantity of kidney beans (*Phaseolus vulgaris*), afforded :—

Of matter analogous to starch	1805
“ Albumen and matter approaching to animal matter in its nature	851
“ Mucilage	799

From 3840 parts of lentiles, he obtained 1260 parts of starch, and 1433 of a matter analogous to animal matter.

The matter analogous to animal matter is described by Einhoff, as a glutinous substance insoluble in water; soluble in alcohol; when dry, having the appearance of glue; probably a peculiar modification of gluten.

From sixteen parts of hempseed, Bucholz obtained three parts of oil, three and a half parts of albumen, about one and three fourths of saccharine and gummy matter. The insoluble husks and coats of the seeds weighed six and one eighth parts.

The different parts of flowers contain different substances: the pollen, or impregnating dust of the date, has been found by Fourcroy and Vauquelin to contain a matter analogous to gluten, and a soluble extract abounding in malic acid. Link found in the pollen of the hazel-tree much tannin and gluten.

Saccharine matter is found in the nectarium of flowers, or the receptacles within the corolla, and by tempting the larger insects into the flowers, it renders the work of impregnation more secure; for the pollen is often by their means applied to the stigma; and this is particularly the case when the male and female organs are in different flowers or different plants.

It has been stated, that the fragrance of flowers depends upon the volatile oils they contain; and these oils, by their constant evaporation, surround the flower with a kind of odorous atmosphere; which, at the same time that it entices larger insects, may probably preserve the parts of fructification from the ravages of smaller ones. Volatile oils, or odorous substances, seem particularly destructive to these minute insects and animalcules which feed on the substance of vegetables; thousands of aphides may be usually seen in the stalk and leaves of the rose; but none of them are ever observed on the flower. Camphor is used to preserve the collections of naturalists. The woods that contain aromatic oils are remarked for their indestructibility; and for their exemption from the attacks of insects: this is particularly the case with the cedar, rose-wood, and cypress. The gates of Constantinople, which were made of this last wood, stood entire from the time of Constantine, their founder, to that of Pope Eugene IV., a period of eleven hundred years.

The petals of many flowers afford saccharine and mucilaginous matter. The white lily yields mucilage abundantly; and the orange lily a mixture of mucilage and sugar; the petals of the convulvulus afford sugar, mucilage, and albuminous matter.

The chymical nature of the colouring matters of the flowers has not as yet been subject to any very accurate observation. These colouring matters, in general, are very transient, particularly the blues and reds; alkalies change the colours of most flowers to green and acids to red. An imitation of the colouring matter may be made by digesting solutions of gallnuts with chalk: a green fluid is obtained, which becomes red by the action of an acid; and has its green colour restored by means of alkalies.

The yellow colouring matters are the most permanent; the carthamus contains a red and a yellow colouring matter; the yellow colouring matter is easily dissolved by water, and from the red, rouge is prepared by a process which is kept secret.

The same substances as exist in the solid parts of plants are found in their fluids, with the exception of woody fibre. Fixed and volatile oils, containing resin or camphor, or analogous substances in solution, exist in the cylindrical tubes belonging to a number of plants. Different species of *Euphorbia* emit a milky juice, which when exposed to air deposits a substance analogous to starch, and another similar to gluten.

Opium, gum-elastic, gamboge, the poisons of the *Upas Antiar* and *Tieute*, and other substances that exude from plants may be considered as peculiar juices belonging to appropriate vessels.

The sap of plants, in general, is very compound in its nature; and contains more saccharine, mucilaginous, and albuminous matter in the alburnum; and most tannin and extract in the bark. The cambium, which is the mucilaginous fluid found in trees between the wood and the bark, and which is essential to the formation of new parts, seems to be derived from these two kinds of sap; and probably is a combination of the mucilaginous and albuminous matter of one, with the astringent matter of the other, in a state fitted to become organized by the separation of its watery parts.

The alburnous saps of some trees have been chymically examined by Vauquelin. He found in those of the elm, beech, yoke-elm, hornbeam, and birch, extractive and mucilaginous matter, and acetic acid combined with potassa or lime. The solid matter afforded by their evaporation yielded an ammoniacal smell, probably owing to albumen: the sap of the birch afforded saccharine matter.

Deyeux in the sap of the vine and the yoke-elm has detected a matter analogous to the curd of milk. I found a substance similar to albumen in the sap of the walnut-tree.

I found the juice which exudes from the vessels of the marshmallow when cut, to be a solution of mucilage.

The fluids contained in the sap vessels of wheat and barley, afforded in some experiments which I made on them, mucilage, sugar, and a matter which coagulated by heat; which last was most abundant in wheat.

The following table contains a statement of the quantity of soluble or nutritive matters existing in varieties of the different substances that have been mentioned, and of some others which are used as articles of food, either for man or cattle. The analyses are my own; and were conducted with a view to a knowledge of the general nature and quantity of the products, and not of their intimate chymical composition. The soluble matters afforded by the grasses, except that from the florin in winter, were obtained by Mr. Sinclair, gardener to the duke of Bedford, from given weights of the grasses cut when the seeds were ripe.

Table of the Quantities of soluble or nutritive Matters afforded by 1000 Parts of different vegetable Substances.

Vegetables or vegetable Substances.	Whole quantity of soluble or nutritive matter.	Mucilage or Starch.	Saccharine matter or Sugar.	Gluten or Albumen.	Extract or matter rendered insoluble during evaporation
Middlesex wheat, average crop	955	765		190	
Spring wheat.....	940	700		240	
Mildewed wheat of 1806.....	210	178		32	
Blighted wheat of 1804.....	650	520		130	
Thick-skinned Sicilian wheat of 1810	955	725		230	
Thin-skinned Sicilian wheat of 1810.....	961	722		239	
Wheat from Poland.....	950	750		200	
North American wheat	955	730		225	
Norfolk barley	920	790	70	60	
Oats from Scotland	743	641	15	87	
Rye from Yorkshire	792	645	38	109	
Common bean.....	570	426		103	41
Dry peas.....	574	501	22	35	16
Potatoes	from 260 to 200	from 200 to 155	from 20 to 15	from 40 to 30	
Linseed cake.....	151	123	11	17	
Red beet.....	148	14	121	13	
White beet.....	136	13	119	4	
Parsnip.....	99	9	90		
Carrots.....	98	3	95		
Common turnips.....	42	7	34	1	
Swedish turnips.....	64	9	51	2	2
Cabbage.....	73	41	24	8	
Broad-leaved clover.....	39	31	3	2	3
Long-rooted clover.....	39	30	4	3	2
White clover.....	32	29	1	3	5
Sainfoin.....	39	28	2	3	6
Lucerne.....	23	18	1		4
Meadow fox-tail grass.....	33	24	3		6
Perennial rye grass.....	39	26	4		5
Fertile meadow grass.....	78	65	6		7
Roughish meadow grass.....	39	29	5		6
Crested dog's-tail grass.....	35	28	3		4
Spiked fescue grass.....	19	15	2		2
Sweet-scented soft grass.....	82	72	4		6
Sweet-scented vernal grass...	50	43	4		3
Fiorin.....	54	46	5	1	2
Fiorin cut in winter.....	76	64	8	1	3

All these substances were submitted to experiment green, and in their natural states. It is probable that the excellence of the different articles, as food, will be found to be in a great measure proportional to the quantities of soluble or nutritive matters they afford ; but still these quantities cannot be regarded as *absolutely* denoting their value. Albuminous or glutinous matters have the characters of animal substances ; sugar is more nourishing, and extractive matter less nourishing, than any other principles composed of carbon, hydrogen, and oxygen. Certain combinations likewise of these substances may be more nutritive than others.

I have been informed by Sir Joseph Banks, that the Derbyshire miners, in winter, prefer oat-cakes to wheaten bread ; finding that this kind of nourishment enables them to support their strength and perform their labour better. In summer, they say, oat-cake heats them, and they then consume the finest wheaten bread they can procure. Even the skin of the kernel of oats probably has a nourishing power, and is rendered partly soluble in the stomach with the starch and gluten. In most countries of Europe, except Britain, and in Arabia, horses are fed with corn of different kinds, mixed with chopped straw ; and the chopped straw seems to act the same part as the husk of the oat. In the mill, fourteen pounds of good wheat yield on an average thirteen pounds of flour ; the same quantity of barley twelve pounds, and of oats only eight pounds.

In the south of Europe, hard or thin-skinned wheat is in higher estimation, than soft or thick-skinned wheat ; the reason of which is obvious, from the larger quantity of gluten and nutritive matter it contains. I have made an analysis of only one specimen of thin-skinned wheat, so that other specimens may possibly contain more nutritive matter than that in the table ; the Barbary and Sicilian wheats, before referred to, were thick-skinned wheats. In England,

the difficulty of grinding thin-skinned wheat is an objection; but this difficulty is easily overcome by moistening the corn.

CHAPTER II.

General View of the Atmosphere, considered in its Relations to Vegetation.

[FROM CHAPTAL'S CHYMISTRY APPLIED TO AGRICULTURE.]

To judge correctly concerning the influence of the atmosphere on vegetation, we must first understand what are the peculiar and distinctive properties of its several elements, and then observe their action on terrestrial bodies.

The atmosphere is composed, for the most part, of two fluids, in the form of gases—viz., azote, or nitrogen, and oxygen; and these, it is ascertained, are everywhere in like proportions to each other, even at the greatest heights that have hitherto been ascended by man. This fact has been confirmed by M. Gay-Lussac, in a comparative analysis of air taken from an elevation of three thousand six hundred toises,* and of that at the surface of the earth.

There are also other fluids existing permanently in the atmosphere, though in extremely variable proportions; of which carbonic acid, water, the electric and magnetic fluids, and heat and light are the principal. These latter exert a very striking influence, not only on vegetation, but on all the phenomena exhibited by terrestrial bodies; and although they do not enter essentially into the composition of the atmosphere, nevertheless, their operation is so intimately combined

* A French toise is two English yards, or six English feet.

with that of its chief constituents, as scarcely to be separable from them. It seems to be required, therefore, in order that the agency of the atmosphere may be the more accurately understood, that we should begin by considering separately the leading properties of the several fluids which it contains, with a view, subsequently, of applying them to the various phenomena which agriculture presents.

ARTICLE I.

Of the Ponderable Fluids contained in the Atmosphere.

The ponderable fluids, which the atmosphere contains, are the gases nitrogen and oxygen, carbonic acid, and water.

1. *Nitrogen gas** constitutes nearly four parts in five of the entire composition of the atmosphere; and yet, as by some strange caprice, this principle appears to exercise the least influence of all upon substances belonging to either of the three kingdoms of nature. It is found in inconsiderable quantities in some of the products of vegetables, and in those of animals abundantly. Still the most careful investigation has, as yet, resulted only in showing a very trifling absorption of this gas either by plants or animals.

The existence of nitrogen in certain of the products of vegetation is referable probably, in part, to a portion of this gas being introduced into plants by the atmospheric air in combination with the water which it holds in solution; and, in part, also to the

* *Azote* or nitrogen is a gaseous substance, not capable of being condensed by any known degree of cold. It does not enter into combustion under common circumstances, but may be made to unite with oxygen by the agency of electrical fire. It may be procured by burning phosphorus in a confined portion of air. The number representing the proportion to which it combines is twenty-six.—*Davy's El. Ag. Chym.* p. 45.

manures by which plants are nourished: of which nitrogen is, in some, a principal constituent.

With respect to animals, in which nitrogen is much more abundant than in plants, the food by which they are supported, and the air inhaled by respiration, equally account for its presence. The experiments of Humboldt and Provencal upon fish, of Spallanzini upon reptiles, and those of Davy, Pfaff, Enderson, Edwards, Dulong and others, upon man, leave no doubt concerning the absorption of nitrogen in respiration; but, inasmuch as this absorption is unequal, irregular, and variable, according to circumstances, it cannot be compared, especially in its effects on the animal and vegetable economy, to that of oxygen.

The action of nitrogen is, in fact, so unimportant as far as it is known, that we are at fault to assign any reason why nature should have been so lavish in its diffusion throughout the atmosphere. It has, indeed, been considered by some in the light of a vast aerial magazine, intended to receive all the gases, exhalations, and vapours, which ascend from the earth's surface; and out of which these are again withdrawn, as they may be needed either for the support of animal life, or to quicken vegetation, or for the production of those numerous phenomena of composition and decomposition, which are incessantly renovating the surface of the globe.

The specific gravity of pure nitrogen gas is to that of atmospheric air in the proportion of 9,691 to 10,000.*

2. *Oxygen gas*† constitutes very nearly one fifth

* Davy says as 9,516 to 10,000.—*El. Ag. Chym.* p. 45.

† *Oxygen* is an elastic fluid, at all temperatures. It supports combustion with much more vividness than common air; so that if a small steel wire or a watch-spring, having a bit of inflamed wood attached to it, be introduced into a bottle filled with the gas, it burns with great splendour. It is respirable. It is very slightly soluble in water. The number representing the proportion in which it combines is

part of the atmosphere; and its specific gravity is to that of the air as 11,036 to 10,000.*

The offices performed by oxygen are alike numerous and important. It is this gas which is the support of animal life in respiration; and which, by combining with the carbon of the blood, becomes the principal agent in the production of animal heat. The germination of seeds is promoted by it, and it is absorbed by the leaves of plants during the night. By its combination with the metals, their various oxides are formed. It is likewise an indispensable agent in combustion; and co-operates powerfully in the production of all animal, vegetable, and mineral decompositions.

Wherever oxygen is brought into action, it combines with some one of the elements of the bodies on which it acts, forming acids with carbon, nitrogen, sulphur, phosphorus, and many of the metals, water with hydrogen, &c. The nature of those compounds, into which oxygen enters as an element, varies in proportion to the quantity of it with which they are combined.

When we consider how extensive and important are the offices performed by oxygen gas, and, especially, that it is constantly employed in the formation of new bodies possessing afterward no resemblance to itself, we are almost ready to fear that the atmosphere, sooner or later, must become exhausted of this active and renovating principle. Nature, however, is unceasingly engaged in repairing these losses, by the production, anew, of equivalent quantities. The leaves of plants, affected by the solar light, are continually pouring forth into the atmosphere torrents of oxygen gas, generated by the decomposition of car-

bon. It may be made by heating a mixture of the mineral called manganese and sulphuric acid together in a proper vessel, or by heating strongly red lead, or red precipitate of mercury.—*Davy's El. Ag. Chym.* p. 43.

* According to Davy as 11,067 to 10,000.—*ib.* p. 43.

bonic acid and water; and of which they appropriate the carbon and hydrogen to themselves.

It is possible, without doubt, that in many instances the reproduction of oxygen may not be proportioned to its waste. This, indeed, cannot fail of being the case wherever a very great consumption of it, either by respiration or combustion, takes place. An effect of this kind, however, can only be partial and momentary; such being the mobility of the atmospheric fluid, that it speedily recovers its equilibrium at all points. The winds, also, by agitating the atmosphere in every direction, so mingle together its elements that the principal fluids of which it is composed are found everywhere, and in nearly constant proportions.

There is neither creation nor destruction of any element throughout the operations of nature. The numerous phenomena of composition and decomposition on the surface of our globe, are nothing more than the continual displacing of some principles and combinations by others; all of which occurs according to laws that are fixed, unchanging, and eternal. It is thus that nature is constantly renovated without being impoverished; and that matter experiences no changes, but such as tend to result, periodically and uniformly, in reproduction especially in organized bodies.*

3. *Carbonic acid* † appears to be present constantly,

* There are many modes of separating the principal constituents of the atmosphere, oxygen, and azote, from each other. A simple one is by burning phosphorus in a confined volume of air: this absorbs the oxygen and leaves the azote; and 100 parts in volume of air, in which phosphorus has been burnt, yield 79 parts of azote; and by mixing this azote with 21 parts of fresh oxygen gas artificially procured, a substance having the original character of air is produced. To procure pure oxygen from air, quicksilver may be kept heated in it, at about six hundred degrees, till it becomes a red powder: this powder, when ignited, will be restored to the state of quicksilver by giving off oxygen.—*Davy's El. Ag. Chym.* p. 200.

† Carbonic acid is composed of two proportions of oxygen 30, and one of carbon 11.4.—*Davy's El. Ag. Chym.* p. 52. The experimental proofs of the composition of carbonic

though in variable proportions, in the atmosphere. Although much heavier than either nitrogen or oxygen, its weight of the same volume being to that of the latter as 1,520 to 1,000 it is still found to be diffused throughout the entire atmospheric region. M. de Saussure, the elder, by the employment of lime water, obtained this gas from the air on the summit of Mont Blanc. While, then, the proportions of nitrogen and oxygen, in the composition of the atmosphere, are proved to be constant and almost invariable, it appears, likewise, to be well established that carbonic acid exists at all elevations, though in proportions by no means uniform.

M. Th. de Saussure, by analyzing portions of atmospheric air, in summer and in winter, and comparing the relative quantities of carbonic acid which they contained, during these different seasons, has furnished the following results:—

In winter—31st January, 1809,	10,000 parts of air	
	contained . . .	Carbonic Acid 4,570
2d of February, 1811,	“ “	4,660
7th of January, 1812,	“ “	5,140
The mean term in winter, taking 10,000 parts		
of air, was,	In volume, . .	4,790
	In weight, . .	7,280

acid gas are very simple. If thirteen grains of well burnt charcoal be inflamed by a burning-glass in one hundred cubical inches of oxygen gas, the charcoal will entirely disappear; and, provided the experiment be correctly made, all the oxygen, except a few cubical inches, will be found converted into carbonic acid; and, what is very remarkable, the volume of the gas is not changed. On this last circumstance it is easy to found a correct estimation of the quantity of pure charcoal and oxygen in carbonic acid gas: the weight of one hundred cubical inches of carbonic acid gas is to that of one hundred cubical inches of oxygen gas, as forty-seven to thirty-four: so that forty-seven parts in weight of carbonic acid gas must be composed of thirty-four parts of oxygen and thirteen of charcoal.—*Davy's El. Ag. Chym.* p. 199.

In summer—20th of August, 1810, 10,000 parts			
of air contained	Carbonic Acid		7,790
27th of July, 1811,	"	"	6,470
15th of July, 1815,	"	"	7,130

The mean term in summer, taking 10,000 parts			
of air, was,	In volume,	. .	7,130
	In weight,	.	10,830

Doubtless when the air is tranquil, or when carbonic acid, so abundantly produced by fermentation, respiration, combustion, &c., is retained in confined situations, the quantity of it thus accumulated, must exceed its ordinary proportion; but so soon as by the agitation of the winds or any other disturbing cause, it comes to be mingled with the atmosphere, it expands and diffuses itself, and that by fixed laws, in every direction.

Unless in extraordinary cases, like those just now mentioned, and which are exceptions to the general rule, the quantity of carbonic acid present in the atmosphere, does not exceed the proportion, at most of one to five hundred. Carbonic acid is constantly being decomposed by the leaves of plants—which retain the carbon for their own nourishment, and throw off the oxygen into the atmosphere. It enters into combination with lime, in fresh mortar, causing it to resume its primitive form of lime-stone. It also dissolves in water, making it slightly acid. This fluid will hold a portion of carbonic acid in solution, of nearly its own volume, under the pressure of the atmosphere; but, if the pressure be increased, it may be made to dissolve a much larger quantity. Water, so charged, will sparkle like champagne—which wine possesses this quality, only from a carbonic acid produced by its fermentation, and its being confined in well-corked bottles. In some experiments, recently made, carbonic acid gas has been reduced to a liquid state by means of pressure.

4. Water* is present in the atmosphere under the form of an elastic fluid.† When it is absorbed by bodies which have a strong affinity for it, as, for example, the calcined muriate of lime, the portion of air, thus drained of its moisture, is, according to M. de Saussure, the elder, and Davy, reduced both in weight and volume. Water is composed of eighty-five parts oxygen and fifteen parts hydrogen.

The quantity of aqueous fluid contained in the atmosphere, varies with the temperature of the latter; being increased or diminished in proportion as this is more or less elevated. At ten degrees Centigrade, or fifty degrees Fahrenheit, it equals in volume nearly one fiftieth of the atmospheric fluid; and its density to that of the atmosphere being as ten to fifteen, it

* Water is absolutely necessary to the economy of vegetation in its elastic and fluid state; and it is not devoid of use even in its solid form. Snow and ice are bad conductors of heat; and when the ground is covered with snow, or the surface of the soil or of water is frozen, the roots or bulbs of the plants beneath are protected by the congealed water from the influence of the atmosphere, the temperature of which in northern winters is usually very much below the freezing point; and this water becomes the first nourishment of the plant in early spring. The expansion of water during its congelation, at which time its volume increases one twelfth, and its contraction of bulk during a thaw, tend to pulverise the soil; to separate its parts from each other, and to make it more permeable to the influence of the air.—*Davy's El. Ag. Chym.* pp. 197, 198.

† If some of the salt called muriate of lime that has been just heated red be exposed to the air, even in the driest and coldest weather, it will increase in weight and become moist; and in a certain time will be converted into a fluid. If put into a retort and heated, it will yield pure water; will gradually recover its pristine state; and, if heated red, its former weight: so that it is evident that the water united to it was derived from the air. And that it existed in the air in an invisible and elastic form, is proved by the circumstance, that if a given quantity of air be exposed to the salt, its volume and weight will diminish, provided the experiment be correctly made.—*Davy's El. Ag. Chym.* pp. 195, 196.

consequently constitutes about one seventy-fifth of its weight, (Davy.)

At the temperature of thirty-four degrees Centigrade, or ninety-three degrees, twenty minutes, Fahrenheit, the aqueous fluid forms one fourteenth of the volume of the atmosphere, and one twenty-onth of its weight.

In his admirable *Treatise on the Hygrometer*, M. de Saussure, the elder, has the following table, showing the weight of the water contained in a cubic foot of air, at different degrees of temperature:—

Degrees of the Hygrometer.	Weight of the water contained in a cubic foot of air at sixty- six degrees, two minutes, Fahrenheit.	Weight of the water contained in a cubic foot of air at forty- five degrees, nine minutes, Fahrenheit
10	0.4592	0.2545
20	1.0926	0.6349
30	1.7940	1.0833
40	2.5634	1.5317
50	3.4852	2.0947
60	4.6534	2.7159
70	6.3651	3.3731
80	8.0450	4.0733
90	9.7250	4.9198
98	11.0690	5.6549

"Consequently," adds M. de Saussure, "I do not think we shall be far from the truth, if, at the temperature of fifteen degrees of Reaumur, or sixty-five degrees, forty-five minutes, Fahrenheit, we assign to a cubic foot of air, saturated with water, eleven grains of the latter fluid."

By the solution of these eleven grains of water in a cubic foot of air, at the temperature of fifteen degrees Reaumur, or sixty-five degrees, forty-five minutes, Fahrenheit, the density of the latter was so much increased,

that the barometer, which before stood at twenty-seven inches, rose to twenty-seven inches, five lines, .79411—that is to say, about twenty-seven inches, six lines; consequently the density of the air, or its volume in the receiver, was increased about one fifty-fourth.

When the temperature of the atmosphere is diminished, and consequently its density increased, the aqueous fluid which it contains is, in part, pressed out of it; appearing then in the form of vapour, and falling to the earth in the state of dew. It is thus by the freshness and moisture of the night air in summer, that vegetation is reanimated, and plants recover from the state of langour occasioned by excessive heat during the day.*

Oxygen and nitrogen, are as yet, classed among the simple bodies, while carbonic acid and water are compounds, of which the constituent principles are known, and which may be formed or decomposed at pleasure.

One hundred parts of carbonic acid contain:—

Carbon, ... 27.36

Oxygen, ... 72.64

One hundred parts of water contain:—

Hydrogen, ... 11.06

Oxygen, ... 88.94

Oxygen and nitrogen are the essential constituents

* Water is composed of oxygen, and hydrogen. If the metal called potassium be exposed in a glass tube to a small quantity, it will act upon it with great violence; elastic fluid will be disengaged, which will be found to be hydrogen; and the same effects will be produced upon the potassium, as if it had absorbed a small quantity of oxygen; and the hydrogen disengaged, and the oxygen added to the potassium, are in weight as two to fifteen; and if two in volume of hydrogen, and one in volume of oxygen, which have the weights of two and fifteen, be introduced into a close vessel, and an electrical spark passed through them, they will inflame and condense into seventeen parts of pure water.—*Davy's El. Ag. Chym.* p. 197.

of the atmosphere; which still retains nearly all its properties of form, elasticity, &c., after the other two principles are, by chymical agents, separated from it. In being reduced to this state, however, it will have parted with most important qualities—those by which it exercises its principal power on vegetation; so that all the substances which exist in the atmosphere, are requisite to the production and renewal of the various phenomena, which the three kingdoms of nature present.

Of the four principles here spoken of, as the constituents of the atmosphere, the aqueous fluid appears to be the least adhesive of all, and the most slightly united to the others; since changes of temperature, alone, suffice to vary indefinitely its proportions; while nitrogen, oxygen, and carbonic acid maintain constantly about the same proportions to each other; nor can they be disunited, or any one of them withdrawn from the others, either by change of temperature, or any degree of pressure.

The aqueous fluid does not rise to a great height in the atmosphere; for it is stated by those who have ascended in air-balloons, that, at a *very great elevation*, they found the air exceedingly dry; and that so rapidly did it absorb the moisture from the boards of the balloon boat, that they shrunk and cracked as if they had been exposed to a strong heat. This was not occasioned entirely, however, by the dryness of the atmosphere; but was owing also, in part, to its diminished specific gravity.

The manner in which the atmospheric elements are united with each other is very remarkable. While this union is sufficiently strong to keep them together, notwithstanding their different specific gravities, and to prevent their being separated either by pressure, or any agitation, however tumultuous, of the atmosphere; it is, at the same time, so feeble, that it is only required to present to them some substance, for which they have a very slight affinity, in order to

decompose and insulate them. Thus if we confine under a bell-glass a portion of atmospheric air, the aqueous fluid may be extracted from it by means of thoroughly calcined muriate of lime; the combustion of phosphorus in this air will absorb from it its oxygen gas; lime-water, or the caustic alkalies, will combine with its carbonic acid, and nothing will finally remain, except nitrogen gas, which has the least tendency of all to combination.

It is necessary that there should be this feeble state of union among the constituent principles of the atmosphere, in order that they may be capable of acting the more effectually, and freely, upon the various substances on the surface of the earth; the composition and decomposition of which can be adequately accomplished by their agency alone.

Besides those bodies which essentially compose the atmosphere, there are exhalations continually rising from the earth's surface, which mix with the air, and are again disengaged from it and precipitated, whenever the heat, or any other cause by which they were forced to ascend, ceases to act upon them. These exhalations, casually mingling with the air, alter its qualities, and impair its purity. They are imbibed by the oxygen and water of the atmosphere, and their particles are deposited by these on other bodies, to which they adhere, or with which they enter into combination. Numerous diseases have no other origin than this; their seeds being conveyed by the air, or the aqueous fluid which is mingled with it. And hence it is that, on the borders of ponds and marshes, or wherever animal and vegetable substances, in large quantities, are undergoing decomposition, intermittent fevers are there endemic; and that the miasm, which is disengaged from masses of animal remains, in a putrid state, proves a prolific source of infection and disease. For the same reason it is sometimes dangerous to inhale the evening dew; inasmuch as the aqueous fluid which composes it, may be charged

with noxious principles, that have been exhaled during the day. Thus fogs and mists, also, are the readiest vehicles of offensive odours. The manner in which the air is perfumed with the aroma of plants, its conveyance of the same to our organs, and the facility with which it becomes impregnated with the odours exhaled from bodies in the process of decomposition, indicate, with sufficient clearness, its influence in the first production of disease; and still more distinctly its power to propagate and to continue those maladies, which are, in their nature, infectious.

ARTICLE II.

Of the Imponderable Fluids contained in the Atmosphere.

Besides the ponderable substances which essentially compose the atmosphere, and those others which are casually mingled with it, it also contains certain imponderable fluids, the effects of which are less certainly known, but which, nevertheless, appear to act a most important part in the production of the atmospheric phenomena; of these the electric fluid is one.

1. *Electricity** is disengaged by friction, and communicated by simple contact. It is accumulated in bodies when they are insulated; and is transmitted in the same manner as heat, when a body not electrified is brought near to another which is.

* Different opinions are entertained among scientific men respecting the nature of electricity. By some the phenomena are conceived to depend upon a single subtle fluid in excess in the bodies said to be positively electrified, in deficiency in the bodies said to be negatively electrified. A second class suppose the effects to be produced by two different fluids, called by them the vitreous fluid, and the nervous fluid; and an hypothesis has been advanced in which they are considered as affections or motions of matter, or an exhibition of attractive powers, similar to those which produce chymical combination and decomposition; but usually exerting their action on masses.—*Davy's El. Ag. Chym.* pp. 39, 40.

The peculiar properties of the electric fluid, and the frequent variations to which it is subject in the atmosphere, are the occasion of numerous phenomena, in respect to which observation and experiment have shed no inconsiderable light.

Whenever the electric principle is abundantly diffused throughout the atmosphere, it appears to exercise a very powerful influence over the phenomena of vegetation; by it the oxygen of the air is excited to action, and it induces the aqueous fluid contained in the same, to condense, and thereby to fall in rain. Davy has observed that grain germinates sooner in water charged with positive electricity, than in that containing the opposite principle;* and it is also well known that fermentation proceeds more rapidly on the approach of a thunder-storm; and that liquids, consisting of an aggregation of particles but slightly united, as milk for example, at such a time, speedily decompose, and become acid.

2. Whatever opinion† we may be induced to adopt,

* I found that corn sprouted much more rapidly in water positively electrified by the Voltaic instrument than in water negatively electrified; and experiments made upon the atmosphere show that clouds are usually negative; and as, when a cloud is in one state of electricity, the surface of the earth beneath is brought into the opposite state, it is probable that in common cases the surface of the earth is positive.—*Davy's El. Ag. Chym.* p. 39.

† Two opinions are current respecting the nature of heat. By one school it is conceived to be a peculiar subtile fluid, of which the particles repel each other, but have a strong attraction for the particles of other matter. By another it is considered as a motion or vibration of the particles of matter, which is supposed to differ in velocity in different cases, and thus to produce the different degrees of temperature. Whatever decision be ultimately made respecting these opinions, it is certain that there is matter moving in the space between us and the heavenly bodies capable of communicating heat; the motions of which are rectilinear: thus the solar rays produce heat in acting on the surface of the earth.—*Davy's El. Ag. Chym.* p. 37.

as to the nature of the principle of *heat*, it is certain that there exists, not only in the atmosphere, but in all terrestrial bodies, an imponderable fluid, unequally distributed among them, and which causes them to be either solid, or liquid, or gaseous, according to the degree of affinity which their particles have to each other, and to the fluid of heat; and this we may regard as the natural state of bodies.

Bodies in this their natural state, exposed to the same atmospheric temperature, are penetrated by unequal portions of the fluid of heat; but since this fluid exists in them as a principle, and, so to speak, in combination with them, it does not manifest its most important property, viz. that of heat: which, in this latent and inactive condition, philosophers have agreed to call caloric. To obtain the name of heat, caloric must be entirely free, and released from all combination.

Interposed between the particles of bodies, it is the uniform tendency of caloric to separate these particles one from another; and, when accumulated in any body beyond its natural proportion, its excess, operating as heat, changes the form of such body; forcing it, if it be a solid, first to assume a liquid form, and, subsequently, that of vapour. Bodies existing naturally as gas, and which have been changed to solids by combining with other bodies, resume their natural form, whenever exposed to a degree of heat sufficient to overcome the affinity, which unites them to their base; while those bodies, which have not been originally constituted to exist in a gaseous form, are made to pass, by a similar application of heat, through all the separate stages between their natural state, and that of invisible vapour; from which again they will return to their original concrete form, whenever such excess of heat ceases to act upon them.

Caloric may be elicited from bodies either by percussion or compression, in the same manner as water is pressed out of a substance which has been

saturated with it. In this case the component particles of any such body are forced closer together, and its porosity, and, consequently, its volume diminished. Striking hard bodies together, or rubbing them one against another, will produce the same effect; the portion of caloric, which is in such cases set free, acting as heat. We can also depress or elevate the temperature of bodies, by bringing them in contact with other bodies which are either colder or warmer than themselves. The fluid of heat will, in this case, continue to pass from one body to the other, until it attains a state of equilibrium; having regard, however, to their respective capacities for caloric, since bodies by their nature, absorb this fluid unequally.

All bodies contain a determinate portion of caloric; and this is the exact quantity required to keep them in their natural state. When, however, in consequence of exposure to variations of temperature, changes in their density take place, they either part with, or absorb caloric, and are thereby made either to contract or to dilate. The gases, while they are becoming solid by entering into combination with other bodies, vapours in being condensed, and solids as they contract, throw off into the air a portion of their caloric, which then becomes heat; while, on the other hand, they absorb caloric when they dilate.

The phenomena of composition and of decomposition, which are constantly succeeding each other on the surface of the globe, occasion, every instant, either the emission or absorption of caloric. Two substances, in combining, may form a compound, which will demand more or less caloric than is contained in both its separate constituent principles; in which case, there must necessarily be produced either cold or heat, during the process of combination. The gases, as they become solid, give out their caloric, and their combination, therefore, produces heat. In combustion, also, in which oxygen gas is the principal agent, there takes place a constant disengagement of caloric; for the

reason that this gas generally forms with combustible substances either solid or liquid compounds, and thereby parts with a portion of the caloric, to which was owing its gaseous form.

These principles being established, we shall find little difficulty in explaining a part of the effects produced on vegetation by the variations of temperature. So great, indeed, during the year, are these variations, that while some liquids are made by turns to pass into a solid or an aeriform state, there are solids, again, which become liquid.

The natural effect of heat on bodies, is to dilate them;* thereby weakening the force of the cohesive attraction by which their particles are united, and facilitating the action of chymical affinity between them and other bodies, to enable them the more readily to form new combinations. It is thus that heat renders the sap of plants more fluid; in consequence of which it circulates with greater freedom through their cells and capillary tubes; stimulating, at the same time, the suckers of their roots, so that they more eagerly imbibe the juices of the earth, &c.

But, above a certain point, the effect of heat is injurious to plants, inasmuch as it produces too great an

* A solid cylinder of metal after being heated will not pass through a ring barely sufficient to receive it when cold. When water is heated in a globe of glass having a long slender neck, it rises in the neck; and if heat be applied to air confined in such a vessel inverted above water, it makes its escape from the vessel and passes through the water. There are, however, a few exceptions to the law of expansion of bodies by heat, which seem to depend either upon some change in their chymical constitution, or on their becoming crystallized. Clay contracts by heat, which seems to be owing to its giving off water. Cast iron and antimony, when melted, crystallize in cooling, and expand. Ice is much lighter than water. Water expands a little even before it freezes, and it is of the greatest density at about forty-one or forty-two degrees, the freezing point being thirty-two degrees; and this circumstance is of considerable importance in the general economy of nature.--*Davy's El. Ag. Chym.* pp. 35, 36.

evaporation of water; in which case, their sap circulates less freely, their juices become thickened in their organs, vegetation ceases, and vitality is suspended. This uniformly takes place during seasons of excessive heat, when neither the quantity of rain which falls, nor the dew, nor irrigation, sufficiently repair the waste of moisture produced by evaporation, and the transpiration of plants.

Such effects would be still more frequent than they are, but that nature, provident in all things, employs means to mitigate the action of heat. The first of these means is the transpiration, itself, of vegetables, which must necessarily draw off from them a great portion of heat, and thereby keep them at a temperature below that of the air. A second means, answering the same end, is supplied by the organization of the leaves of plants, through which their transpiration is for the most part carried on. That side of the leaf which is exposed directly to the sun, is covered with a thick cuticle, which reflects the calorific rays. In herbaceous plants, as, for example, in the stems of grasses, this covering is chiefly composed of silex; while in other vegetables it is analogous to resin, wax, gum, or honey. But the cuticle which covers the other side of the leaf, is, on the contrary, thin and transparent; and it is through this surface, that both transpiration and the absorption of the nutritive principles of the atmosphere are carried on. If we reverse this established order of things, by turning a leaf so as to present its under surface to the sun, we shall see it very soon making every effort in its power to recover its natural position.

When a plant is dead, or, more properly, when a plant that is annual has accomplished the object of its being, by the formation of seeds or fruit to secure its reproduction, neither the action of heat or of other agents, chymical or physical, is any longer modified by the causes just mentioned; but the plant, in this

state, is subject to their effects, without any mitigation.

When the temperature of the atmosphere is greatly diminished, the fluids of plants are thereby condensed, the circulation of their juices becomes languid, the activity of their organs is impaired, and their vital functions are enfeebled, and finally suspended, until by the return of heat they are again resuscitated. The action of atmospheric cold upon plants is modified by the emission or disengagement of caloric, which is always given out by liquids as they condense, and by solids while they contract; for which reason the temperature of plants, during the winter, is, at all times, a little above that of the atmosphere.

But it occasionally happens, that the temperature of the atmosphere is depressed so low, as to produce the most fatal effects upon plants, congealing their sap, and thereby causing their death. These results, however, are not always proportioned to the degree of cold, but depend in part upon other circumstances in connexion with it. I have seen olive-trees resist a cold of $22^{\circ}.2$ Fahrenheit; and, again, I have seen them perish under a temperature of $28^{\circ}.6$; and for the reason that, in the latter case, the snow, which had covered their branches during the night, being dissolved by the heat of the sun the following day, the trees, while still wet, were exposed to the last-named degree of cold during the succeeding night. There is, indeed, nothing more dangerous to grasses and the cereal plants, than frost coming immediately after a thaw, since, by being in a wet state, and their roots having only a feeble hold on the soil, which has been made spongy and loose by freezing, they are altogether without defence against the cold.

3. Sennebier was the first to advance the opinion, that light is injurious to the germination of seeds; and this was afterward confirmed by the experiments of Ingenhouz. But M. de Saussure, who experimented on this subject, by placing seeds under two receivers,

the one opaque and the other transparent, was convinced that they germinated in both cases, in the same time; but that the subsequent vegetation was more vigorous and rapid under the transparent receiver than under the opaque. These opinions, though seemingly so contradictory, are, nevertheless, easily reconciled, by keeping in view the distinction which exists between the action of light and that of heat. Since plants transpire very little during the first period of their growth, if, in this stage, they be exposed to the combined influence of these two fluids, their evaporation, not being sufficient to temper the effects of the heat, it will act upon them with all its force, and thus their delicate organs will be scorched and withered. It is on this account that gardeners are so careful to protect their seed-beds from the sun, and not to expose to it their tender plants, until, by the growth of their leaves, and their consequently increased transpiration, they are enabled to mitigate the fervid heat of its rays.

Although the action of light upon vegetation appears not to be so important as that of the other fluids which we have mentioned, it is still no less real. Plants which grow in the shade, or in darkness, have neither the colour, nor perfume, nor flavour, nor consistence of those which receive the direct rays of the sun; and although the luminous fluid may not actually enter into the combinations which take place in the organs of plants, the formation of such combinations is without doubt greatly promoted by it.

It is the general opinion that the leaves of plants give out oxygen gas, only when they are exposed to the direct rays of the sun; and it is known, also, that flowers rarely produce fruit if they be kept constantly in the shade. If the sensitive plant be placed in the shade, it will, according to the observations of M. De Candolle, close its leaves, as in the night; and immediately open them again, on being exposed either to the sun, or to an artificial light.

The beautiful discoveries of Herschel have shed

much light, in relation to these curious inquiries. This ingenious philosopher has shown that, of the different rays which compose a pencil of light, there are some which possess, almost exclusively, the property of being luminous, and others, that of imparting heat: and to these facts, so very important, Wollaston and Ritter have added another—that there is still a third species of rays, which appear designed to act upon bodies, as most effective chymical agents.

If, then, we consider the all-powerful influence which is exercised upon vegetation by the atmosphere, and its agency in the most important processes connected with rural economy, such as fermentation, the preparation of various materials, and the decomposition of different substances, to be applied to their several uses in husbandry; we cannot but be surprised at the entire absence, among agriculturists, of those cheap and simple instruments, which indicate its variations, and make known its state during every moment of the day.

I do not recommend the procuring of delicate and complicated instruments; but I should be glad to find in the possession of every farmer, an hygrometer to ascertain the degree of humidity in the atmosphere, a thermometer to indicate its temperature, and a barometer to determine its density. The last-named instrument would be particularly valuable, to foreshow the changes of the weather; a rising of the mercury preceding very generally the return of dry weather, and its depression indicating the approach of rain or storms. It is true that these variations of the barometer can be regarded only as signs; but then they are signs greatly more to be depended upon, than such as are ordinarily resorted to: as, for example, those which by farmers are so confidently deduced from the moon, in her different quarters.

CHAPTER III.

On the Nature of the Earths, and their Action upon Vegetation.

[FROM CHAPTAL'S CHYMISTRY APPLIED TO AGRICULTURE.]

NEARLY all plants are indebted to the earth for their support. Still there are some, the seeds of which being lodged upon trees by the winds or by birds, they there germinate, and the plants attain, in this situation, their natural growth; as the mistletoe, the mosses, &c. There are others, again, which float upon the waters; and still others which attach themselves to barren rocks, or to dry slates, tiles, &c., and of this latter kind are "*les plantes grasses*," pulpy or fleshy plants. Since then, the earth affords support to by far the greatest number of plants, and to all those which are necessary to man, its effects upon vegetation present to us a subject of vast importance, and, at the same time, one of the most difficult that can be discussed.

Plants are not constituted, like animals, with the faculty of locomotion; but perpetually confined to the same spot of earth, they are obliged to supply all their wants from the narrow space which they occupy. They can lay under contribution nothing more than the trifling portion of air, earth, and water, with which they come directly in contact; and are, therefore, compelled to seek for the nutritive principles indispensable to their growth, and to the exercise of their faculties, immediately around them. It is, consequently, necessary that they should be enabled freely to extend their roots, for the purpose of drawing from a distance the nourishing juices of the soil; and, also, that they may fasten themselves firmly in the earth, so as neither to be withered by the heat, nor uprooted by the winds.

These conditions, however, so indispensable to a flourishing vegetation, are not always found united in

the soils appropriated to agriculture; and this leads us to investigate the nature of soils, and the differences which exist among them.

ARTICLE I.

Of Vegetable Mould.

All plants, when dead, more or less rapidly undergo decomposition; and in this process, which is greatly promoted by the air, moisture, and heat, new products are formed; with which it is the more important that we should become acquainted, inasmuch as the principal aliment of living plants is derived from the remains of those which have died.

Decomposition is the more rapid in plants of a pulpy and succulent nature, or if they be collected together in large masses; but it is in all cases greatly accelerated both by moisture, and a high degree of atmospheric temperature. During the whole time that this process is going on, carbonic acid gas, produced partly by the combination of the constituent principles of the plants, and partly by the oxygen of the atmosphere acting upon their carbon,* is, in large quantities, being evolved; hydrogen,† also, which is generally carbu-

* *Carbon* is considered as the pure matter of charcoal, and it may be procured by passing spirits of wine through a tube heated red. It has not yet been fused; but rises in vapour at an intense heat. Its specific gravity cannot be easily ascertained; but that of the diamond, which cannot chymically be distinguished from pure carbon, is to that of water as three thousand five hundred to one thousand. Charcoal has the remarkable property of absorbing several times its volume of different elastic fluids, which are capable of being expelled from it by heat. The number representing it is 11.4.—*Davy's El. Ag. Chym.* pp. 45, 46.

† *Hydrogen*, or inflammable air, is the lightest known substance; its specific gravity is to that of air as seven hundred and thirty-two to ten thousand. It burns by the action of an inflamed taper, when in contact with the atmosphere. The proportion in which it combines is represented by unity, or one. It is procured by the action of diluted oil of vitriol, or

retted, and furnished, probably, by the decomposition of the watery particles, and likewise, ammoniacal gas,† if its elements exist in the plants, are, at the same time, being exhaled.

Vegetable substances, collected in large masses, always give out heat during their fermentation; but, when they are in a dry state, they must be slightly moistened, before they will ferment and decompose. The heat, in this latter case, may even be carried so far as to set on fire the entire mass; which not unfrequently happens, when hay has been stacked before it is sufficiently dry, or when cordage, hemp, or flax, have been piled up in a wet state.

When plants become entirely decomposed, there is left an earthy residuum of a brownish colour, which is called vegetable mould; and in this, besides the salts and earths which it contains, are found certain extractive principles and oils, which have escaped decomposition.

The distillation of vegetable mould in a retort yields carburetted hydrogen gas abundantly, a portion of carbonic acid gas, bituminous empyreumatic oil, and water holding in solution pyroligneous acid and carbonate of ammonia.

These analyses by fire, however, do not give to us substances as they actually exist in vegetables or animals; of which the natural products become, by this process, decomposed, and we are presented with their elements differently combined from what they originally were.

The analysis of vegetable mould, by washing it in water, will acquaint us far better with the nature of its component principles, and its action on vegetation. M. de Saussure, by taking pure vegetable mould from

hydro-sulphuric acid on filings of zinc or iron. It is the substance employed for filling air-balloons.—*Davy's El. Ag. Chym.* p. 45.

* Ammonia, or the volatile alkali, consists of six proportions of hydrogen and one of nitrogen.

the open field, and leaching it in boiling water, found it to afford, after twelve successive decoctions, a quart of dry extract equal to 1-11 of its weight. He obtained from rich garden mould, and from the mellow soil of a field bearing a good crop, the same extract, though in less quantity. This ingenious philosopher is of the opinion that the fertility of soils does not depend on the quantity of extract which they contain.

Vegetable mould, which has been deprived, in part, of its extractive matter by washing, yields nearly the same elements as that which is entire, by distillation; but it is not as strong in the former state as in the latter, nor as capable of supporting vegetation.

Then, after repeated decoctions, vegetable mould ceases to afford any additional quantity of extract, if it be moistened, and left exposed to the air for the space of three months, a fresh supply from it may be obtained. These macerations, when repeated for a long time on the same mould, uniformly produce coloured infusions, the colouring particles of which also furnish the extract (Saussure); and this proves that, in the successive changes of vegetable products, new combinations take place, and that from these certain compounds are derived, which are soluble in water, even when that fluid has apparently exhausted its solvent power on the separate bodies themselves. This fact is of great importance, inasmuch as it shows that vegetable manures may retain their nutritive qualities through the whole period of their decomposition, by continuing to form new products, which, being soluble in water, serve as aliment to plants. It also shows that substances, which are *themselves* insoluble in water, may, nevertheless, become excellent manures, by affording certain soluble *products*, during the several stages of their decomposition.

Vegetable mould, when deprived of its extract, yields rather more carbon than before. M. de Saussure found it to contain thirty-three and one fourth in the former, and but thirty-one in the latter state. Of

one hundred parts of the dry extract of turf mould, there remained fourteen parts of ashes; and these, leached with boiling water, gave twenty-five hundredths of pure potash, muriates, and alkaline sulphates.

It is proper to remark that when vegetable mould has been reduced to ashes, these will be soluble in water, in proportion to the intensity of the heat to which they have been subjected; where this is very great, a sort of semitritfaction takes place, which, by uniting the earthy constituents with the alkaline salts, renders the whole less soluble in water. M. de Saussure has shown that, of the salts contained in the ashes of mould, there cannot be extracted by means of boiling water, a quantity exceeding at most, two hundredths; whereas, by the same method, he obtained from the dry extract of turf mould five hundredths in alkaline salts, and, subsequently, by another kind of analysis, a similar amount.

With the exception of the saline and earthy principles contained in vegetable mould, in the proportion of five to seven per cent., the rest are all completely destructible by the action of air and water. Mould immersed in water, or kept from contact with the air, does not undergo any decomposition; but when it has imbibed a portion of water, and is exposed to the action either of atmospheric air, or of oxygen gas, this latter, combining with the carbon of the mould, produces a quantity of carbonic acid gas, uniformly equal in volume to that of the water imbibed. If this water be sufficiently impregnated with carbonic acid, the volume of air in contact with the mould, under a bell-glass, will undergo no change.

The carbon taken from mould, by its combining with oxygen, is not in proportion to the loss which is produced by decomposition; carburetted hydrogen and water are still disengaged, owing to the combination of the oxygen with the hydrogen, and of this latter with the carbon. The decomposition of vegetable

mould is exceedingly slow, and when promoted by the united action of air, heat, and water, it is not even then fully accomplished until after several years.

It is to the presence of principles analogous to those contained in vegetable mould, that land for the most part, at least, owes its fertility. These principles are supplied by manures, and by the decomposition of vegetables; but each successive crop diminishes their quantity; a portion being carried off by the water, and another portion being absorbed by the plants which annually grow upon the soil. In this way soils may become gradually exhausted of their nutritive principles; until finally nothing is left but an earthy residuum, destitute of alimentary juices, and completely steril. For which reason, it is indispensably necessary, that after a succession of crops, lands should be manured afresh, in order to restore their fertility.

ARTICLE II.

Of the Nature of Soils.

The subject of which we are about to treat, is one of the most difficult which agriculture presents; but as it is, at the same time, of all others, perhaps the most important, it will claim our most diligent attention, and the utmost care to point out correctly the diversities existing among arable lands, and their distinctive properties.

It is the earth which furnishes support to nearly all plants; and since this is greatly diversified in its character, and every class of plants requires a particular kind of earth adapted to their growth, it becomes especially necessary that we should study the nature of soils, in order that we may become enlightened respecting the cultivation of plants; for these not only derive their principal nourishment from the soil, but, upon its qualities, many of their physical properties also greatly depend.

Arable lands, of which alone we propose to speak,

are generally composed of silica,* lime,† alumina,‡ magnesia,§ oxyde of iron,|| and certain saline substan-

* *Silica*, or the earth of *flints*, in its pure and crystallized form, is the substance known by the name of rock crystal, or Cornish diamond. As it is procured by chymists, it appears in the form of a white impalpable powder. It is not soluble in the common acids, but dissolves by heat in the fixed alkaline lixivia. It is an incombustible substance, for it is saturated with oxygen. I have proved it to be a compound of oxygen and the peculiar combustible body which I have named *silicium*; and from the experiments of Berzelius, it is probable that it contains nearly equal weights of these two elements.—*Davy's El. Ag. Chym.* p. 147.

† The sensible properties of *lime* are well known. It exists in soils usually united to carbonic acid, which is easily disengaged from it by the attraction of the common acids. It is sometimes found combined with the phosphoric and sulphuric acids. It is soluble in nitric and muriatic acids, and forms a substance with sulphuric acid difficult of solution, called gypsum. It is not soluble in alkaline solutions. It consists of one proportion forty of the peculiar metallic substance, which I have named calcium; and one proportion fifteen of oxygen.—*Davy's El. Ag. Chym.* p. 147.

‡ *Alumina* exists in a pure and crystallized state in the white sapphire, and united to a little oxyde of iron and silica in the other oriental gems. In the state in which it is procured by chymists, it appears as a white powder, soluble in acids and fixed alkaline liquors. From my experiments, it appears that alumina consists of one proportion thirty-three of aluminum, and one fifteen of oxygen.—*Davy's El. Ag. Chym.* pp. 147, 148.

§ *Magnesia* exists in a pure crystallized state, constituting a mineral like talc found in North America. In its common form it is the *magnesia usta*, or calcined magnesia of druggists. It generally exists in soils combined with carbonic acid. It is soluble in all the mineral acids; but not in alkaline lixivia. It is distinguished from the other earths found in soils by its ready solubility in solutions of alkaline carbonates, saturated with carbonic acid. It appears to consist of thirty-eight magnesium and fifteen oxygen.—*Davy's El. Ag. Chym.* p. 148.

|| There are two well known *oxydes of iron*, the black and the brown. The black is the substance that flies off when red-hot iron is hammered. The brown oxyde may be formed by keeping the black oxyde red-hot for a long time in contact

ces.* The various proportions in which these materials exist in soils give to them their different characters; and they are distinguished by the names of siliceous, calcareous, argillaceous, magnesian, etc., as the several substances, indicated by these terms, predominate in their composition.† These names are necessary in order to class the different soils according to their several characters, and to show the degree of fertility possessed by each, and the kind of culture to which they are respectively adapted.

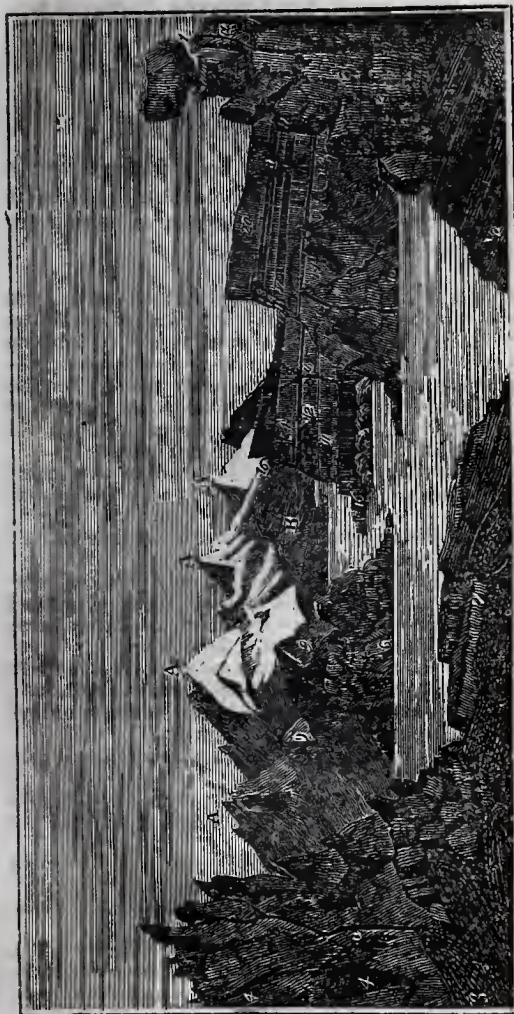
By itself, no one of these earths affords a basis for successful husbandry; but, by mixture, they are made to correct the defects of each other. The best soil is that, in which is united the greatest number of properties adapted to the promotion of vegetation.

Besides these earthy and saline principles, there are few soils which do not also contain, more or less abundantly, vegetable and animal substances in a state of decomposition; and on the proportions in which these latter are found to exist in different soils, will depend,

with air. The first seems to consist of one proportion of iron one hundred and three, and two of oxygen thirty; and the second of one proportion of iron one hundred and three, and three proportions of oxygen forty-five. The oxydes of iron sometimes exist in soils combined with carbonic acid. They are easily distinguished from other substances by their giving, when dissolved in acids, a black colour to solution of galls, and a bright blue precipitate to solution of prussiate of potassa and iron.—*Davy's El. Ag. Chym.* p. 148.

* The *saline compounds* found in soils, are common salt, sulphate of magnesia, sometimes sulphate of iron, nitrates of lime and of magnesia, sulphate of potassa, and carbonates of potassa and soda.—*Davy's El. Ag. Chym.* p. 149.

† The earthy matters are the true basis of the soil; the other parts, whether natural, or artificially introduced, operate in the same manner as manures. Four earths generally abound in soils; the aluminous, the siliceous, the calcareous, and the magnesian. These earths, as I have discovered, consist of highly inflammable metals united to pure air or oxygen; and they are not, as far as we know, decomposed or altered in vegetation.—*Davy's El. Ag. Chym.* pp. 11, 12.



- | | | | | |
|----------------------|-------------------|-------------------------|--------------|-----------------------|
| 1 Granite | 6 Porphyry | 11 Siliceous Sandstone | 15 Basalt | 21 Plum-Pudding Stone |
| 2 Gneiss | 7 Granular Marble | 12 Limestone | 17 Coal | A A Primary Mountains |
| 3 Micaceous Schistus | 8 Chlorite Schist | 13 Shale | 18 Gypsum | B Secondary Mountains |
| 4 Sienite | 9 Quartzose Rock | 14 Calcareous Sandstone | 19 Rock Salt | aaa Veins |
| 5 Serpentine | 10 Grauwacke | 15 Iron Stone | 20 Chalk | |

other things being equal, their relative degree of fertility.

ARTICLE III.

On the Formation of Arable Lands.

Nearly all arable lands have been formed by the decomposition of the rocks, which constitute the basis of our globe,* and in the carrying on of which decomposition various causes concur.

* Rocks and strata from which soils have been derived, and those which compose the more interior solid parts of the globe, are arranged in a certain order; and as it often happens that strata very different in their nature are associated together, and that the strata immediately beneath the soil contain materials which may be of use for improving it, a general view of the nature and position of rocks and strata in nature will not, I trust, be unacceptable to the intelligent farmer.

Rocks are generally divided by geologists into two grand divisions, distinguished by the names of *primary* and *secondary*.

The primary rocks are composed of pure crystalline matter, and contain no fragments of other rocks.

The secondary rocks, or strata, consist only partly of crystalline matter, contain fragments of other rocks or strata; often abound in remains of vegetables and marine animals; and sometimes contain the remains of land animals.

The primary rocks are generally arranged in large masses, or in layers, vertical or more or less inclined to the horizon.

The secondary rocks are usually disposed in strata or layers, parallel, or nearly parallel, to the horizon.

The number of primary rocks which are commonly observed in nature are eight.

First, *granite*, which is composed of quartz, feldspar, and mica; when these bodies are arranged in regular layers in the rock, it is called *gneis*.

Second, *micaceous schistus*, which is composed of quartz and mica, arranged in layers, which are usually curvilinear.

Third, *sienite*, which consists of the substance called hornblende and feldspar.

Fourth, *serpentine*, which is constituted by feldspar and a body named resplendent hornblende; and their separate crystals are often so small as to give the stone a uniform appear-

The waters, rushing in torrents from the tops of the mountains, furrow their sides, and impetuously sweep away with them the fragments of rock, which they

ance; this rock abounds in veins of a substance called *steatite*, or *soap-rock*.

Fifth, *porphyry*, which consists of crystals of feldspar, embedded in the same material, but usually of a different colour.

Sixth, *granular marble*, which consists entirely of crystals of carbonate of lime; and which, when its colour is white, and texture fine, is the substance used by statuaries.

Seventh, *chlorite schist*, which consists of chlorite, a green or grey substance, somewhat analogous to mica and feldspar.

Eighth, *quartzose rock*, which is composed of quartz in a granular form, sometimes united to small quantities of the crystalline elements, which have been mentioned as belonging to the other rocks.

The secondary rocks are more numerous than the primary, of which we shall notice the following varieties:—

First, *grauwacke*, which consists of fragments of quartz, or chlorite schist, imbedded in a cement, principally composed of feldspar.

Second, *siliceous sandstone*, which is composed of fine quartz or sand, united by a siliceous cement.

Third, *limestone*, consisting of carbonate of lime, more compact in its texture than in the granular marble; and often abounding in marine exuviae.

Fourth, *aluminous schist or shale*, consisting of the decomposed materials of different rocks cemented by a small quantity of ferruginous or siliceous matter; and often containing the impressions of vegetables.

Fifth, *calcareous sandstone*, which is calcareous sand, cemented by calcareous matter.

Sixth, *ironstone*, formed of nearly the same materials as aluminous schist or shale; but containing a much larger quantity of oxyde of iron.

Seventh, *basalt or whinstone*, which consists of feldspar and hornblende, with materials derived from the decomposition of the primary rocks; the crystals are generally so small as to give the rock a homogeneous appearance; and it is often disposed in very regular columns, having usually five or six sides.

Eighth, *bituminous or common coal*.

Ninth, *gypsum*, the substance so well known by that name, which consists of sulphate of lime; and often contains sand.

Tenth, *rock salt*.

have detached. These fragments are carried along more or less rapidly by the currents of rivers; in their progress, their sharp points and angles are worn off by

Eleventh, *chalk*, which usually abounds in remains of marine animals, and contains horizontal layers of flints.

Twelfth, *plumb-pudding stone*, consisting of pebbles cemented by a ferruginous or siliceous cement.

The highest mountains are constituted by granite; and this rock has likewise been found at the greatest depths to which the industry of man has as yet been able to penetrate; micaceous schist is often found immediately upon granite; serpentine or marble upon micaceous schist; but the order in which the primary rocks are grouped together is various. Marble and serpentine are usually found uppermost; but granite, though it seems to form the foundation of the rocky strata of the globe, is yet sometimes discovered above micaceous schist.

The secondary rocks are always incumbent on the primary; the lowest of them is usually *grauwacke*; upon this limestone or sandstone is often found; coal generally occurs between sandstone or shale; basalt often exists above sandstone and limestone; rock salt almost always occurs associated with red sandstone and gypsum. Coal, basalt, sandstone, and limestone, are often arranged in different alternate layers, of no considerable thickness, so as to form a great extent of country. In a depth of less than five hundred yards, eighty of these different alternate strata have been counted.

The veins which afford metallic substances, are fissures vertical or more or less inclined, filled with a material different from the rock in which they exist. This material is almost always crystalline; and usually consists of calcareous spar, fluor spar, quartz or heavy spar, either separate or together. The metallic substances are generally dispersed through, or confusedly mixed with these crystalline bodies. The veins in hard granite seldom afford much useful metal; but in the veins in soft granite and in gneis tin, copper, and lead are found. Copper and iron are the only metals usually found in the veins in serpentine. Micaceous schist, sienite, and granular marble are seldom metalliferous rocks. Lead, tin, copper, iron, and many other metals, are found in the veins in chlorite schist. *Grauwacke*, when it contains few fragments, and exists in large masses, is often a metalliferous rock. The precious metals, likewise iron, lead, and antimony, are found in it; and sometimes it contains veins, or masses of *stone coal*, or coal free from bitumen. Limestone is the great metalliferous rock of the secondary family; and lead and copper

continually jostling and rubbing against each other; their forms in this way become gradually rounded, their surfaces smooth, and their size diminished; until, at length, the particles of which they were composed form successively gravel, sand, and finally mineral mould.

The stony particles which constitute these deposits, and the slime which unites them, are finely pulverised in proportion to the distance they have been brought, as the rock itself has been more or less hard, and as the currents of water, by which they have been transported, were more or less rapid.

The soils of nearly all our rich valleys owe their origin to the decomposition of rocks; and we may judge of their character, and the elements of which they consist, by being previously acquainted with those composing the mountains, of which they are the spoils. Thus the ruins of granitic mountains, consisting of quartz, feldspar, and mica, form soils containing silica, alumina, lime, magnesia, and oxyde of iron; mountains of the quartz-formation, composed almost wholly of siliceous earth, give origin to soils of an analogous character, and so of the rest.

It would be erroneous, however, to suppose that soils, formed from the fragments of mountains, are altogether of the same nature, and that they contain the same principles, and in like proportions, as the rocks from which they have been derived. For this to be so, it would be previously required that all the

are the metals most usually found in it. No metallic veins have ever been found in shale, chalk, or calcareous sandstone; and they are very rare in basalt and siliceous sandstone.

In cases where veins in rocks are exposed to the atmosphere, indications of the metals they contain may be often gained from their superficial appearance. Whenever fluor spar is found in a vein, there is always strong reason to suspect that it is associated with metallic substances. A brown powder at the surface of a vein always indicates iron, and often tin; a pale yellow powder lead; and a green colour in a vein denotes the presence of copper.—*Davy's El. Ag. Chym.* pp. 182-187.

earths, composing these rocks, should be of the same specific gravity, and that they should possess the same affinity to water; which is by no means the case. If then we consider that, when they are all reduced to a like degree of fineness, some of these earths, from their greater weight, must be deposited, while others less heavy, are carried along by the current, it will appear evident that silica, and the oxyde of iron, since they are the heaviest of all, must predominate in the deposits first formed, and then successively lime, alumina, and magnesia, in the order of their specific gravities.

It is exceedingly interesting to observe attentively the diversities existing in alluvial soils, both in relation to the distribution and intermixture of their constituent principles, and their different characters, according as they are more or less remote from the sources whence they have been brought.

Besides the inequality in the specific gravity and hardness of the different earthy principles, there are other natural causes, which powerfully co-operate in producing the varieties observable among alluvial soils. Rivers along their course, receive tributary streams, which mingle the earthy particles they bear along, with the slime of those into which they flow; and hence arise innumerable differences of character, in the deposits which are formed. This mixture of the slime of different rivers frequently forms deposits, possessing a higher degree of fertility, than if they had been derived from either one of them alone; the deficiencies, or bad qualities in one, being corrected by what is supplied from another. In this way the fragments brought down from mountains of the quartz formation, mixing with the argillaceous and calcareous particles derived from mountains of a different character, produce a soil which is far more fertile, than if it had been formed of the decompositions of any one of these mountains separately.

Thus the soils now employed in the most flourishing

and productive husbandry, are nothing more than the wrecks of those majestic mountains, from whose sides fragments of rock have been rent away, and borne along by impetuous torrents, until in their course they have been reduced to minute particles, which are finally deposited in the valleys, to form the basis of agriculture.

It is doubtless to the causes already mentioned, that we must refer the formation of the arable soils of valleys; but along the sides of mountains, and on those extensive table-lands which crown their tops, they must have had a different origin. The continued action of air and water alone, might indeed be sufficient to produce these results; but this action could only be extremely slow, and its effects scarcely perceptible in the lapse of centuries, unless other agents had concurred in hastening the decomposition of the rocks, and their conversion into productive soil.

The decomposition of rocks is rapid in proportion as they are less compact, and more permeable by water; and, on the other hand, it is more slow, as the particles of which they are composed are more closely united to each other, and as they possess less affinity for air and water, and refuse to combine with these agents.

To account for the action of air and water upon rocks, we are to consider that many of them contain lime, very imperfectly saturated, and, generally, oxyde of iron also, at its lowest state of oxydation; so that the lime is constantly disposed to absorb from the atmosphere its carbonic acid, while the oxyde of iron combines with its oxygen. These combinations will take place rapidly, unless the lime and the oxyde of iron be united with, and, so to speak, resolved and incorporated into other substances, which, in consequence of their not possessing the same affinities for the air, resist its action; in which case another agent must be introduced, to break up their intimate union; and this agent is water.

Water, in frequently moistening the surface of rocks, and remaining for a longer or shorter time upon them, penetrates slightly into their mass; after awhile it makes its way through the first stratum, and gradually insinuates itself into the fissures; the cold converting it, in this situation, into ice, by its expansion in freezing, it separates and forces apart the nearest particles; access being thus afforded to the action of the air, this combines its principles with the lime and the oxyde of iron; the surface of the rock has now essentially changed its character, and from this time the process of decomposition goes on more rapidly. In this state, the lichens and mosses succeed in fastening themselves to the surfaces of rocks, and assist slowly in their change; their slender roots insinuate themselves into the pores and crevices; by continued efforts they at length break through the partitions by which these are separated, and thus they gradually form thin successive layers of pulverized matter.

Water, in its ordinary operation, by slowly penetrating some one of the earthy principles of rocks will, after a long time, produce the same results; but its action becomes far more rapid and powerful, during its transition to a state of ice.

When the surface of the rock has been thus broken, and the lichens and mosses have once attached themselves, to it, other plants, which require but little earth for their support, spring up, and, again decaying, by successive decompositions they gradually form a soil, which in process of time becomes sufficiently deep for the cultivation of every kind of vegetable.

In the preceding remarks, we have noticed only the action of such natural causes, as account for the formation of arable lands; and it is doubtless to these that we are originally indebted for nearly all the soils, which are now employed in agriculture; the productiveness of which, however, has been greatly increased both by the labour of man, and the successive decay of vegetables.

Large stones, which had escaped pulverization in the formation of the alluvial soils, and which obstructed their cultivation, have been gradually removed; where soils were originally too stiff, or in any respect defective, they have been improved by the judicious admixture of other earths; soils of every kind have been rendered more fertile by vegetable remains, and the manure of animals; and man has been taught by experience what plants are suited to each variety of soil, and their best modes of culture. Nature provides the soil; and by the industry of man, it is fitted to produce abundantly, as well for the gratification of his tastes, as for the supply of his necessary wants.

But what constitutes the difference among soils, and what are the kinds best adapted to agriculture?

In considering the nature of the different rocks, by the decomposition of which all soils have been originally formed, and which, notwithstanding the changes which they have undergone from vegetable decay, and the labours of man, still retain their distinctive character, we shall find the following varieties:—

Among the primitive rocks, or those of the earliest formation, granite undoubtedly ranks the first. It is found to consist generally of an aggregation, more or less compact, of several kinds of rock, differing from each other in form, colour, hardness, and the materials of which they are composed; and these rocks are, most commonly, feldspar, quartz, and mica. These again, either separately, or by some two combining together, form other rocks; as, for example, quartz, which is almost entirely without mixture, and of which some of the primitive mountains are composed; and micaceous schist, formed by quartz and mica, arranged in strata which are sometimes curvilinear.

I shall treat only of these particular kinds of rock, since the others occur in smaller masses, and none of them occupy the same extent on the earth's surface.

Neither shall I notice certain substances, as hornblende, amphibole, serpentine, &c., which are found more or less blended with granite, and are in this connexion altogether secondary.

The different rocks, of which granite is formed, vary widely from each other in their composition. Quartz consists almost entirely of siliceous earth; feldspar, of silex, alumina, lime, potash, and the oxyde of iron; and mica contains, in addition to these, magnesia. The decomposition of granite, therefore, forms soils, which, on being analyzed, uniformly afford these several principles; while those which have originated from quartz mountains, are one entire bed of siliceous earth; and others again, produced by micaceous schist, contain the elements only of feldspar and mica.

Calcareous mountains, composed of the carbonate of lime, and containing no remains of organized bodies, are ranked by naturalists among the primitive rocks; and the deposits derived from them form calcareous soils.

All the soils, which have been produced by the decomposition of the primitive rocks, should be designated by the name of primitive, to distinguish them from others which are of a different origin.

But besides the causes already alluded to, and which have doubtless produced by far the largest proportion of our arable lands, there are also others to which many kinds of soil owe their origin.

The convulsions by which the earth has at different times been agitated; the decomposition of the beds of pyrites,* which appear to have once covered a portion of its surface; the draining of numerous lakes, as well by the hand of man as by themselves occasionally bursting through the barriers by which they were confined; eruptions of volcanoes; the overflow

* Sulpherets of iron and copper, with a portion of alumina and silex.

ings of the sea ; the osseous remains of animals, and masses of vegetable matter buried in the earth, have contributed to the formation of a great variety of soils, which have subsequently been appropriated by man to his own purposes.

ARTICLE IV.

Of the Composition of Arable Lands.

There would be no difficulty in determining the character of the different soils, if we had merely to consult that of the rocks from which they have severally been derived ; but vegetable growth and decomposition, time, and the labours of man, have been productive of so many changes, that their primitive character has almost disappeared, and we are obliged to consider them in their actual state.

Arable soils consist, for the most part, of silex, lime, and alumina ; but with these are intermixed various kinds of pebbles or of sand, in dissimilar proportions : and, in like manner, the remains of animal and vegetable substances, in different stages of decomposition. Other materials are also found by analysis to exist in soils : but not commonly in such quantities that they can properly be classed among their elements ; and, when they are too abundant, as is sometimes the case with respect to magnesia and the oxyde of iron, in certain localities, the soil is thereby rendered less fit for vegetation.

It is a mixture then of lime, silex, and alumina, which constitutes the basis of a good soil ; but, in order that it may possess every desirable quality, these elements must be combined in such proportions as, by analysis, are found to exist in the very best soils.

I shall inquire, therefore, in the first place, what these definite proportions are ; and then describe the properties peculiar to each variety of fertile soil, and their effects in order to show how the faults of one

soil may be corrected by the addition of another; and, lastly, I shall speak of the adventitious admixture of animal and vegetable matter with soils, and their fertilizing effects; concluding this head with a brief explanation of several methods, by which agriculturists may ascertain the character of their lands.

In order to know what, under different climates, are the earthy constituents of the most productive soils, we must refer to analyses made of them by individuals, upon whose skill and accuracy we may confidently rely.

One of the most fertile soils in Sweden was found by Bergmann to contain:—

Coarse silex	30
Silica	26
Alumina	14
Carbonate of lime	30
	100

Giobert analyzed a portion of rich soil from the environs of Turin, the earthy constituents of which were in the following proportions:—

Silica	77 to 79
Alumina	9 to 14
Carbonate of lime	5 to 12

The most fertile mixture composed by Tillet, in a great number of experiments made by him at Paris, consisted of three eighths clay, three eighths finely pulverized lime-stone, and two eighths sand; which, after being reduced to their elements, afforded:—

Coarse silex :	25
Silica	21
Alumina	16.5
Carbonate of lime	37.5

An excellent wheat soil in the neighbourhood of West Drayton, in Middlesex, yielded to Davy three fifths of siliceous sand; and two fifths of three different earths minutely divided, and in the following proportions:—

Carbonate of lime	28
Silica	32
Alumina	39*

I take no notice here either of water or of animal and vegetable remains, which enter into the composition of soils in the proportion of about one tenth, compared with the earths which they contain. In analyzing a portion of very rich alluvial soil from the banks of the Loire, at a distance of three hundred and seventy-five miles from its source, I found it composed of:—

Siliceous gravel	32
Calcareous do.	11
Silica	10
Carbonate of lime	19
Alumina	21
Vegetable remains	7

A soil in Touraine, on which was growing a luxuriant crop of hemp, afforded to me by analysis:—

Coarse gravel	49
Carbonate of lime	25
Silica	16
Alumina	10

It would appear from these analyses, that the best soils contain a large proportion of gravel; the effect of which is to separate the minute particles, and to render them loose and moveable, so as to allow the superabundant water to filtrate freely through them. If, again, we appeal, by analysis, to the poorer soils, we shall discover that these are less fertile, in proportion as they contain either of the three principal earths in excess; and that they are almost entirely sterile, where they exhibit the properties of one alone.

* The results of this analysis are stated by Davy as follows:—

Carbonate of lime	28
Silica	32
Alumina	29
Animal or vegetable matter and moisture	11

El. Ag. Chym., p. 166.

It is evident, then, that for the formation of a good soil, a mixture of the different earths is indispensably necessary; nor do the proportions of these admit of being varied, except in accommodation to climate, and the kinds of plants intended to be cultivated. Calcareous and siliceous earths may, without injury, constitute a larger proportion of the soil in humid countries than in dry; and, again, alumina may be more abundant in lands, from which, on account of their declivity, the water runs off freely; still it is only by a mixture of the three earths that we can have a fertile soil, and too great a disproportion among them materially deteriorates its quality.

There is in the constituent particles of soils a constant tendency to more minute division. By continual tillage, and the concurrent action of salts, manures, and frost, this division may become so extreme, that at length a soil may be reduced to a fine powder or dust; in which state, it will be destitute of substance, and cease to be productive; the rain falling upon it will convert it into mere mire or mud; and this being hardened by the heat of the sun, the air will be excluded, and the roots of plants will be wholly unable to fulfil their functions.

According to the observations of Davy, whenever a soil consists of nineteen twentieths of impalpable matter, it is completely steril. Manure may partially correct this condition of things, but its effects will be merely momentary, and the only way to give permanent fertility to such soils, is to mix with them coarse sand and gravel, to render them less compact.

It would appear that the three earths which constitute the basis of fertile soils enter into the composition of plants. This has been shown by Bergmann, in analyzing different kinds of grain; and the experiments of Ruchert upon different vegetable products, place it beyond a doubt. About one hundred parts of ashes well leached, and consequently deprived of nearly all their salts, gave to him:—

	Silica.	Lime.	Alumina.
The ashes of wheat. .	48	37	15
“ oats .	68	26	6
“ barley. .	69	16	15
“ rye .	63	21	16
“ potatoes .	4	66	30
“ red clover	37	33	30

All soils do not contain these three earths. There are some which consist of a combination of only two, as, for instance, of silica with alumina, and of the latter with carbonate of lime, &c.; and occasionally we even find some single one of them united with quartzous or calcareous sand, and forming, in this connexion, a cultivable soil.

There are generally other substances, which enter into the composition of the soils just mentioned, in addition to the two alluded to; but then they are so unimportant, compared with these, which impart their own character to the mass, that they need not be particularly noticed.

A mixture of silica and alumina constitutes the soil which is known by the name of *clayey*, *argillaceous*, or simply *clay*. The properties of alumina predominate in all such soils, nor are they ever fertile where this earth forms as much as one half of their composition; in which case, they can only be employed in the manufacture of certain kinds of potters' ware, for which purpose they are well adapted; and especially, if their remaining portion consist of *silex* minutely divided.

I have had occasion to analyze a portion of the soil of three different fields, situated on a plain composed almost entirely of argillaceous marl. The first afforded

Silex in grains	17
Alumina	47
Silica	21
Carbonate of lime	10
Carbonate of magnesia	5
Oxide of iron	2

The second:—

Silex in grains	22
Silica	15
Alumina	45
Carbonate of lime	11
Carbonate of magnesia	4
Oxyde of iron	3

The third:—

Silex in grains	19
Silica	24
Alumina	40
Carbonate of lime	9
Carbonate of magnesia	5
Oxyde of iron	3

The other principles consisted of the remains of manures but little decomposed.

All these soils are unproductive, and become adhesive and clammy when wet; the water which stands upon them is uniformly turbid and whitish, and particularly so when it is agitated by wind; the effect of heat is to contract and crack their surface, to make it hard, and render it impenetrable to the plough; nor can they be made to any considerable extent productive, but by the liberal application of coarse undecomposed manures, and, especially, by ploughing in crops of buckwheat when in flower.

Soils which have been formed from the fragments, or by the decomposition of mountains of calcareous freestone, or of those composed of carbonate of lime, whether primitive or secondary, frequently consist only of a mixture of calcareous sand, the grains of which are united by a comminuted carbonate of the same nature. These soils are generally light, open, and well adapted to various kinds of culture, especially in humid climates; they require, however, to be of good depth, and to rest upon a sub-soil sufficiently compact to retain the degree of moisture necessary to the plants which grow upon them. This description of soil is suited to the cultivation of the vine, and more espe-

cially of sainfoin; and when well manured, will produce good crops of rye, oats, and barley. Soils of this character are distinguished by the name of *calcareous*, for the reason that, although they almost always contain other principles, the properties of the carbonate of lime so predominate in them, that those of the remaining substances are scarcely observable.

The mixture of alumina and lime constitutes another kind of soil, which is by itself but indifferently productive, whenever more than one half of its mass consists of the former earth: it may, however, be employed with advantage in the improvement of other soils. Its distinctive name is *marl*, or *marly* soil.

The nature of this soil is exceedingly various, and depends upon the proportions of its constituent principles. The name of *argillaceous*, or *fat*, is given to it, when the qualities of alumina predominate in it; and that of *calcareous*, or *poor*, when the calcareous sub-carbonate imparts to it its character. Marl frequently contains the fragments of shells, its beds being sometimes composed almost wholly of their remains; as, for example, the *fahluns*. This soil is the poorest of all, and, at the same time, the best suited for improving argillaceous soils. The fat marls are often mixed with siliceous sand, making it more compact; and are well adapted to correct the defects of calcareous and light soils, generally. I have known marl, which contained seventy parts of sand, twenty of alumina, and ten of carbonate of lime, to be applied with advantage to soils wholly calcareous.

Marl generally occurs in beds, at a slight depth below the surface of the earth. After it is dug out and exposed to the air, it puts on different appearances, according to its quality. The combined action of air and water most commonly disunites its particles, and reduces it to a powder; but its decomposition is much more rapid and complete when its two earths are duly proportioned to each other, than when either one of them is in excess.

The water gradually dissolves and carries away the alumina; the air unites its carbonic acid with the lime not yet entirely saturated; while its oxygen attacks the iron, which is scarcely separable from marls, and increases its oxydation; so that, at length, an actual change in the nature of this earth takes place, and it acquires properties which it did not possess before: it is now reduced to a powder, in which state it is employed to correct and render fertile other earths.

When marl consists of a large proportion of clay, the effect of fire is to harden it, so that it will become sonorous, like well-baked potter's ware. If it be almost wholly calcareous, the fire will convert it into lime; and I have seen a kind, in the Cevennes, which, in its natural state, was so mixed with calcareous sand, that it formed, by itself, an excellent mortar, after being calcined.

The two earths of which marl is composed, vary very greatly in their proportions. I have made numerous analyses of the different marls used in the centre and south of France, and have found that the quantity of sub-carbonate of lime, which they contained, varied from ten even up to sixty per cent.; of that of alumina from fifteen to fifty, and of siliceous sand from fifteen to seventy per cent. Marl is frequently formed by the decomposition of silex or flint.

ARTICLE V.

Of the Properties of the different Earths.

Since the earths composing the soils of which we have just spoken, do not all possess the same qualities, and are very differently acted upon by the air, water, and heat, the three most powerful agents in vegetation, it is evident that a soil will be productive, in proportion as the fertilizing properties of the several kinds of earth are united in it; and that these, moreover, must be duly mixed, in order that the good qual-

ities of one may be made to correct either the defects or the bad qualities of another.

But in order to be able to compose these mixtures in a way that they will correct what is defective in different soils, so that they shall be adapted to a particular kind of culture, it is necessary that we should be acquainted with the distinctive properties of the several earths; and on this subject I now propose to speak.

Siliceous earth, or *silica*, is found in all the hard primitive rocks, and of quartzeous mountains it composes nearly the entire substance. To obtain this earth in its greatest purity, a portion of rock-crystal is to be fused with six parts of potash; it must then be dissolved in water, and deprived of its alkali by muriatic acid; this solution should be evaporated to dryness, and the residuum being washed in water, pure silex will remain. Silica, in this state, has the appearance of a white impalpable earth: it is harsh to the touch, and in water its particles are very rapidly precipitated, and appear not to have any tendency to unite with each other. The weight of silica, compared with that of water, is as 2.5 to 1.

It is insoluble in all the acids, except the fluoric,* which dissolves it, and has the power of separating it from glass, of which it is a constituent. The hot alkaline lixivium slightly corrode it. It is found some-

* *Fluorine*, or the fluoric principle, has such strong tendencies to combination, that as yet no vessels have been found capable of containing it in its pure form. It may be obtained, combined with hydrogen, by applying heat to a mixture of fluor, or Derbyshire spar, and sulphuric acid; and in this state it is an intensely acid compound, a little heavier than water, and which becomes still denser by combining with water. The existence of fluorine as an element is proved by its expulsion from certain compounds by chlorine, and by its transference from place to place. In attempts made to confine it, so as to examine its properties, it always combines with, or decomposes the vessels employed; so that, as yet, its physical qualities are unknown.—*Davy's El. Ag. Chymistry*, p. 14.

what abundantly in plants, into which it could be introduced only by being excessively comminuted, or by being dissolved, perhaps, in one of the alkalies.

This earth is not affected by the action either of fire or of water; it being saturated with oxygen, and according to Davy and Barzelius, composed of equal parts of oxygen, and a base called silicum.

My own experiments show that this earth, which is dry and impalpable, scarcely absorbs one fourth of its own weight of water; and that it allows it to evaporate twice as soon as carbonate of lime, and five times more rapidly than alumina, both being of the same degree of firmness.

All the compound primitive rocks contain *alumina*. To obtain this earth in a pure state, it should be precipitated from a solution of alum, of which it forms the base, by means of the carbonate of ammonia; this precipitate must then be washed, and the residuum being heated, perfectly pure alumina will be obtained; in this state, it puts on the form of a white powder, which has the following properties:—

It is astringent to the taste;

Its specific gravity is from twenty-two to twenty-three;

It hardens in fire, is greatly contracted by it, and becomes no longer soluble in water;

It greedily absorbs water, taking up twice and a half its own weight before it is saturated, and is very tenacious in retaining it, especially when the portion, which softened its surface, is evaporated; nor does it part with it entirely, except at the highest degree of temperature, and when it is in a state of fusion.

Alumina, saturated with water, forms a soft smooth paste, easily worked, and readily receiving any form which one may choose to give it.

According to the experiments of Barzelius, it is composed of 46.70 parts of oxygen, and 53.30 of *aluminium*.

Lime enters into the composition of nearly all the

primitive rocks, and constitutes the basis of all the calcareous mountains, both primitive and secondary.

It may be obtained pure by calcining, at a high degree of temperature, Iceland spar, primitive marble, &c., or by their being dissolved in the acids, and then precipitated. Lime is acrid and caustic to the taste. It absorbs water greedily, and with a hissing sound, and forms with it a hydrate, or the paste, which constitutes the basis of mortar. Carbonic acid, for which it has a strong affinity, combines with it, and gradually separates from it the water, which evaporates. Pure lime consists of 28.09 parts of oxygen, and 71.91 of calcium.*

Lime, as it exists in cultivated soils, is in the form of a carbonate, and possesses properties widely different from those which characterize it in a pure state. Its specific gravity is 2.0. The pulverized carbonate absorbs 0.8 of its own weight of water, and retains it with less tenacity than does alumina.

A mixture of these different earths possesses the properties, which must necessarily result from a combination of the qualities by each one separately introduced; but besides the action of these principles upon each other, manures, the air, water, and the labours of man, are constantly producing modifications in the character of soils, which it is important to understand.

I proceed, therefore, to inquire what influence these several agents exercise in relation to the different soils; and I engage in the discussion of this subject the more readily, from the consideration that it will make known to the agriculturist the philosophical principles of correct practical husbandry; and explain to him numerous phenomena, which he has hitherto noticed, but for which he has been unable, probably, to assign any satisfactory reason.

We have already observed that two of the constit-

* The metallic substance, which in combination with oxygen, forms lime.

uent principles of plants are supplied by the atmosphere; one of which (carbonic acid) assists in their nutrition by affording to them carbon; while the other (oxygen) abstracts from them a portion of carbon. This latter is also the principal agent in the decomposition of manures, and of vegetable remains; nor is the atmosphere limited in its action to the offices here mentioned, important as they are.

The atmosphere may be considered as a vehicle, loaded at all times with a greater or less quantity of water in a state of vapour, a portion of which, owing to the diminished temperature of the night, it parts with, and deposits on the earth. The surface of the ground, and the leaves of plants are observed frequently to be wet in the morning; and the returning sun and heat evaporate this moisture, to fall again, in like manner, the succeeding evening and night. By this alternate movement, arising from the changes of temperature which take place during the twenty-four hours, plants are constantly supplied with water; and thus preserved from being injured by the excessive heat, which, but for this, would wither and dry up their organs.

The aqueous vapours suspended in the atmosphere begin to be condensed, and to fall at, or shortly before, the setting of the sun; and they bring down with them the greater part of the emanations which have ascended from the earth during the day. These emanations, thus deposited, form a portion of the nourishment of plants, and are, in almost all cases, beneficial to them, though often dangerous and hurtful to man; and it is not without reason that he fears and avoids the evening dew. While the heat is more intense in southern climates, and rain, at the same time, less frequent than in northern, the dews are far more abundant, and form the chief support of vegetation.

In order that plants may be benefited as much as possible by the night-dews, it is necessary that the soil should be in a particular state, and different from

what it frequently is. If it be compact and hard, with a crust upon it that is impenetrable to the air, the dew which falls remains upon its surface, and soon after the rising of the sun, it is evaporated, without either softening the earth or moistening the roots of the plants; so that the leaves alone receive any advantage from it; while the roots, which are far more important in supplying nutriment to plants, are in no degree benefited by it.

It is, therefore, requisite that the soil should be frequently stirred, and that it be kept in a loose and open state, so that the air may freely penetrate it, and convey to the roots of plants, and to the earth around them, the moisture with which it is charged. The plant will then be in a situation fully to enjoy the fertilizing effects of the dew, by imbibing it through all its pores; and this process is carried on far more durably by the roots than by the other organs, inasmuch as being protected from the direct action of the sun's rays, and the evaporation about them being consequently more slow, they continue moist long after the leaves have become entirely dry from the heat; the earth also, by being moistened with the dew, greatly facilitates the action of the roots, as well in extending themselves as in imbibing from the soil its nutritive juices. And this naturally leads us to the consideration of a practice in husbandry, the beneficial effects of which all admit.

When such vegetables as peas, beans, potatoes, &c., are sowed in furrows, at some considerable distance apart, the space left between the plants for their free development, is carefully dug or ploughed; by which means the earth is rendered light, porous, and accessible to the air. The advantages derived from this process, have been attributed, by agriculturists, to the destruction of the weeds, which would otherwise exhaust the soil, and obstruct the growth of the cultivated plants. It is said, also, that the earth, by being made loose and porous, is in a better state to

receive and distribute the water which falls in rain. No doubt the benefits here mentioned are real; nor are they by any means unimportant; still I consider them, after all, as being only secondary and subordinate; and that by far the greatest benefit derived to the growth of plants, by lightening up the soil around them, is, from the access thereby afforded to the air, so that it may freely deposite its dews upon their roots and slightly moisten the earth about them.

I have long noticed the effect of this operation in the cultivation of the beet-root, and have found it to be uniformly so speedy and beneficial that I have employed no other means to restore the plants to a healthy state, when at any time they began to turn yellow, and become drooping. In three or four days the colour of their leaves will change to a lively green, and they will commence growing afresh; and this notwithstanding there may have been no rain, and though the soil, previous to the ploughing, contained not a single weed; and I have noticed the same effect with regard to all the roots.

I had long been familiar with a method almost uniformly practised in the culture of the vine, in the south of France, without being able to discover a reason for it. In that country, where it very rarely rains in summer, they lay bare the bottom of every vine-stock, by digging a circular trench about it, deep and broad enough to expose its foot and a portion of the roots uncovered, and which is soon overspread by the leaves of the vine. The only benefit which I can imagine to be derived from this practice is, that by it the air is freely admitted to the roots, so that it can deposite upon them the dew with which it is there much more abundantly charged than in colder climates; and if this be not its effect, it is evident that it would only expose the plant to be dried up by the long-continued and intense heat of the sun.

But soils, owing to their different degrees of fineness, according as their constituent particles are more

or less minutely divided, and also to the different nature of the substances of which they are composed, have not all the same affinity for water. Generally speaking, the more finely the materials of a soil are pulverized, the better will they absorb water.

The absorbing power of the different elements, which compose a fertile soil, may be stated in the following order:—

Vegetable substances.

Animal substances.

Alumina.

Carbonate of lime.

Silica.

Alumina, and the soils in which its properties predominate, do not dispose of the moisture which they receive from the atmosphere to the greatest advantage; they retain water too tenaciously; and the plants which grow on them, suffer as much from drought as though they were in a sandy soil.

Those soils which are light, porous, and composed of due proportions of alumina, sand, carbonate of lime, silica, and vegetable and animal remains, are the best constituted for absorbing and retaining the moisture of the atmosphere, so as to convey it regularly, and in the most beneficial manner, to the organs of plants.

The experiments of Davy have established results which are exceedingly valuable to agriculture. By these experiments, he has ascertained the comparative energy with which different soils absorb the moisture of the atmosphere; proving that those which are the most fertile possess this power in the highest degree; and so uniform is this rule, that the fertility of soils may be estimated and classed by it alone.

One thousand parts of a portion of the celebrated soil of Ormiston, in East Lothian, of which more than half its weight was finely divided matter, consisting, when dried at a temperature of 212° Fahrenheit, of eleven parts carbonate of lime and nine parts vegetable matter, gained eighteen grains in weight by ex-

posure to the atmosphere saturated with moisture at a temperature of 62° .

One thousand parts of a very fertile soil, formed by the deposits of the river Parret, in Somersetshire, gained sixteen grains.

One thousand parts of soil from Mersey, in Essex, gained thirteen grains.

One thousand grains of fine sand from Essex gained eleven grains.

One thousand grains of coarser sand gained eight grains.

One thousand grains of the soil from Bagshot Heath gained only three grains.

The absorbent power of soils was found, indeed, to be uniformly proportioned to their fertility, and to the favourableness of their situation.

Nothing in the science of agriculture is more important than accurately to ascertain the comparative susceptibility of the different soils to absorb humidity from the atmosphere, and their different degrees of tenacity in retaining it. The means to obtain this knowledge are of the simplest character, and within the command of every farmer. It is merely required to dry an equal weight of the different kinds of soil in the same state of fineness, and then to weigh them night and morning for several days, to determine the quantity of moisture which they have each absorbed during the night. But that these results may be perfectly accurate, in every experiment all the different portions of earth must be of the same weight and fineness, equally dry, and spread out of equal thickness.

It will be perceived from what has been already said, that air and water are highly important agents in the process of vegetation. Their action is twofold; first, by affording out of their own decomposition the principles of vegetable nutrition; and secondly, by operating as solvents of other substances, and at the same time serving as vehicles to convey them to the organs of plants.

But if these agents convey to plants their aliment, it is heat alone, by stimulating their organs, which enables them to elaborate it, and fit it for their use. This effect of temperature is observable not only in plants, but in different species of animals, and in the insect tribes especially, nearly all of which become torpid from cold, and are resuscitated by returning heat.

All soils are not equally favourable for receiving and retaining heat. The whitish earths are least easily warmed. Soils in which white clay or aluminous marl predominate, are almost uniformly humid, and contain but little heat. Chalky, calcareous, and white earths, generally, are slow to receive heat, but part with it reluctantly. The coloured earths the most readily absorb heat, and this tendency is increased in proportion as they become darker from brown to black.

It was observed by Davy, that a black soil, consisting nearly one fourth of vegetable matter, acquired, after an hour's exposure to the sun, an elevation of temperature, which raised the thermometer from sixty-five to eighty-eight degrees; while a soil, the basis of which was chalk, was, under the same circumstances, heated only to sixty-nine degrees. The black soil in this experiment being carried into the shade, at a temperature of sixty-two degrees, the thermometer fell in half an hour fifteen degrees, while the chalky soil, at the same exposure, and during the same time, lost but four degrees.

Equal portions of fertile brown soil and of steril clay were dried, and their temperature raised to eighty-eight degrees; in this state, they were exposed to a temperature of fifty-seven degrees, when, in the space of half an hour, the brown soil lost nine degrees, and the clay six degrees. Moist clay, with a temperature of eighty-eight degrees, on being exposed to one of fifty-five degrees, was reduced to the latter temperature in less than one fourth of an hour.

The difference in the natural temperature of soils,

and their greater or less affinity for heat, whether in absorbing or retaining it, are worthy the attention of agriculturists. A good thermometer is the only instrument required in making these experiments; and by such simple means, we may be enabled to determine which particular soil is best suited to this or that species of plants, since they do not all require either the same degree or the same continuance of heat.

Most agriculturists are acquainted with the fact, that the different earths absorb unequal quantities of heat, under the same temperature; and there are some who turn this knowledge to good account. In managing the level spots on the sides of the Alps, it is customary to cover the beds of snow with a black earth, in order that they may thaw the snow, and that the soil may be earlier in a state for cultivation. Similar means are resorted to, to accelerate vegetation in green-houses and in orangeries; that is, by blackening the walls, and spreading soot over the soil, to concentrate and increase the heat. M. de Saussure made the following experiment. In the month of July, he took a box lined with blackened cork, the opening of which was closed by three plates of glass at some distance apart, and at an elevation of eight thousand four hundred and twelve feet, on the Cramont mountain, and at a temperature of forty-three degrees, he found the thermometer which he had placed in the box to rise, in the space of between two and three hours, to $99^{\circ} 50'$.

Besides the heat naturally imparted by the atmosphere to soils, and the modifications which, according to the different nature and colour of their constituent principles it undergoes from them, it may be elevated or depressed to any desired point, by artificial means. Manures disengage heat, and more or less abundantly, according to their nature and the stage of fermentation which they are in. Those which are not decomposed give out the greatest quantity, and keep it up for the longest time. The dung of sheep and horses

is of a warmer nature than that of neat cattle; and black and brown manures heat a soil more than either marl or chalk.

ARTICLE VI.

Of the Properties of Mixed Soils and the Means of rendering them productive.

I trust that, in the preceding articles, I have sufficiently elucidated the origin of soils, their different character, their composition, and their influence upon vegetation; whether this influence be exerted through their constituent principles, or less directly by the modifications produced in them by the action of the atmosphere, heat, &c. It now remains to speak of certain circumstances, which tend to modify the character of soils, and with which the agriculturist should be acquainted.

I have stated, both in the present chapter and in that in which I treat more particularly of manures, that the matter resulting from vegetable and animal decomposition, in connexion with the constituent principles of the atmosphere and of water, compose the aliment of plants. I have remarked, also, that since plants are stationary, their food must be brought to them, and presented to their organs in a state readily to be absorbed by them; and that the organs of plants, by being excited to action through the stimulating power of heat, were enabled to decompose the different substances which they appropriate for nutriment; and so to elaborate them, as to form from them all the different vegetable products.

But in order that all these nutritive principles may be turned to the best account, it is required that they be supplied to plants in proportion to their wants; and, consequently, that the decomposition, to which most of them are subject, should be neither too rapid nor too slow. These modifications appear to be dependant chiefly on the soil, which serves as a regulator of

the other agents; being a vast magazine, in which are stored up nearly all the aliments of plants, and which should be in a state to furnish them uniformly, and in due proportion to the wants of vegetation.

The individual properties of the several earths which constitute a soil, contribute, by their union, to this end. Chalk and silica, by themselves, soon part with water; but a mixture of them with alumina retains it, so that plants suffer less from drought, whereas they would be alternately inundated and dried up, if the latter earth were absent. Pure clay will neither allow the roots of plants to extend themselves, nor the air to penetrate to them; but with silica, carbonate of lime, and sand, it forms a porous mixture, possessing these essential properties. Chalk preserves vegetable and animal substances from too rapid decomposition. A combination of alumina with the oils forms a saponaceous mixture, which may be introduced into plants, thus supplying them with two principles, both of which, separately, are insoluble in water.

The composition of soils may be varied in accommodation to climate, without any diminution of their fertility. The annual quantity of rain which falls in different countries, is so dissimilar, that even within no greater extent than that of France, it varies according to locality, from twenty to thirty inches; and at Turin, as stated by Giobert, to thirty-four. In some countries it is almost continually cloudy, and the atmosphere is loaded with moisture; while in others the sun is scarcely once obscured for the space of six months together. Now it is evident that in countries where the atmosphere is ordinarily humid, and where rain falls abundantly, the soil may, without disadvantage, be more calcareous than argillaceous; and that the best soils in these different countries may vary materially, as to the proportions of the earthy ingredients of which they are composed.

Again, the character of soils should be suited to the nature of the plants proposed to be cultivated in them;

of these, some prefer a loose, dry, and arid soil ; others delight in one that is constantly humid ; some require a great degree of heat, while others vegetate in the midst of snows. These distinctive preferences of plants should be known to the agriculturist ; and he should appropriate to the different kinds, the soils which they severally most affect ; or, if he have no such soils, he should so modify the character of those he has, as to fit them for this end.

But, in order that plants may flourish, it is not always sufficient that soils are suitably composed ; still other conditions are required, which in many cases are found wanting. Arable soils, for example, which have a rock basis, vary greatly in depth ; and this not only has an influence on the growth of plants, but it also determines what particular kinds may be cultivated on them. The bed of earth, should in such cases, be at least ten or twelve inches thick for grain, and more for clover and sainfoin. For trees, again, its depth should be much greater than for these plants, since, otherwise, their roots, by running very near the surface, would send up numerous shoots, or offsets, and thus greatly exhaust the soil at a considerable distance. Trees are frequently seen growing on mountains, where there is scarcely the slightest covering of vegetable mould ; but, in these instances, their roots penetrate into the clefts and crevices of the rocks, which are filled with earth, and even into the substance of the rock itself, where this is sufficiently soft and porous. Thus the finest chestnuts are seen growing, in the Cévennes and at Limosin, upon granite, and freestone rock ; the celebrated vines, also, of the Hermitage flourish on the decomposed surface of rocks of granitic formation.

The character of the substratum on which soils rest is by no means unimportant ; when this is composed of sand, they will dry much sooner, than when it consists of marl or clay. A bed of clay beneath a sandy soil contributes to its fertility, by arresting and retain-

ing the water, as it filtrates through the sand, and thus a degree of moisture is constantly preserved; but if the roots be too long immersed in the water collected on the surface of the clay, the plants will languish. While I have uniformly observed that running water was in no degree prejudicial to the roots of plants, I have no less constantly found that, in a stagnant state, it was not only highly injurious, but generally fatal to them. It is on this account that agriculturists, enlightened by experience, resort to draining, to carry off the superfluous water from their fields and meadows. And, for the same reason, where the soil is too wet, flints or pebbles are sometimes, to a considerable depth, spread over it, and then covered with vegetable mould. In this way I have seen formed excellent meadows, where 'rushes only would grow before.

Argillaceous, or marly soils, resting upon beds of calcareous or porous rock, are more fertile than when the rock, in such cases, is hard and impervious to water. The reason of this is obvious; in the case first supposed, the superfluous water will filtrate freely through the rock, leaving the soil above sufficiently dry; while in the latter, being prevented by the nature of the rock below from passing off, it will remain in the soil, making it tenacious and clammy, and wholly unfit for vegetation.

Again, the fertility of lands, and, also, the nature of their productions, depend greatly upon position. Those with a southern exposure become sooner dry than such as decline toward the north; but then vegetation is more active in such lands, and the quality of their productions is greatly superior.

The form also of lands is the occasion of numerous varieties in their character. Lands which are sloping do not retain moisture as well as those that are level, and vegetation upon them is less luxuriant; but, to compensate for this, their products are of a superior quality. Wines of the same grape, and grown on

precisely the same kind of soil, are quite different, where a vineyard is situated partly on the side, and partly at the foot of a hill.

Lands with a steep declivity, and especially if the soil be loose and porous, are exposed to have their manures washed away by heavy rains, the soil itself frequently sharing the same fate; being sometimes deeply furrowed by ravines, which even lay bare the rocky basis on which it rests. This is often the case with cultivated lands on the sides of mountains, which, from this cause, become at last totally barren; and hence the danger of grubbing and cultivating the soil on the steep sides of mountains; since for the transient benefit of a single crop, the land may be reduced to a condition of protracted sterility.

Soils composed of the same earthy principles, and in the same proportions, afford very different results, according to the nature and the quantity of salts which they contain. Several of these I have mentioned, as being generally found in plants; and which, from this circumstance, we must suppose to be favourable to vegetation. But then they must be present in due proportions, and cannot fail of being hurtful whenever they are too abundant. These salts, however, are not to be classed among the substances which actually constitute the food of plants; they are merely auxiliaries, though powerful ones, in the process of nutrition. The organs of plants require to be excited, and the salts and heat act upon them as stimulants. The salts are to these organs, what marine salt and the different spices are to the stomach of man. And, in addition to their operation as stimulants, they act chymically on the aliments of plants, by combining with them; thereby causing some of them to be soluble in water, while they retard the decomposition of others; so as, at the same time, to quicken, and to regulate, the process of vegetation.

It is evident, merely from the manner in which the salts act upon vegetation, that they should be supplied

only in certain definite proportions; since if they be over abundant, and, at the same time, easily soluble, the water will introduce too great a quantity of them into the organs of plants, whereby these will become irritated, and withered; so that a soil of the very best earthy constituents may be rendered absolutely steril by containing an excess of salts.

Well directed tillage helps greatly to increase the productiveness of soils. But that even this may afford the most profitable results, regard must be had to circumstances which are too frequently overlooked.

Ploughing crumbles the soil, and renders it spongy and light; intermixes its constituent principles, extirpates the weeds, and by burying them in the earth, disposes them to rot; it also rids the ground of different kinds of insects in which it abounds.

Heavy, compact soils require, therefore, to be more frequently ploughed, and with greater care, than those which are light and porous. Argillaceous soils should be ploughed only when they are dry; for if this be done while they are in a wet state, and of the consistency of a soft paste, none of the ordinary good effects will follow; it will, in fact, be nothing more than turning up ridges in the mud.

Sandy and calcareous lands may, on the other hand, be ploughed in any state.

Deep ploughings are of great advantage to soils which have a uniform character to a considerable depth, since, in addition to the usual benefits attending this operation, that portion of the soil which has been made rich by the manure that the rain, in its descent, has carried down with it, is brought to the surface to promote vegetation.

Deep ploughings are useful, also, when the top soil, being of a clayey nature and too compact, has beneath it a stratum of sand or carbonate of lime; for by turning up these earths, which are of a dry and absorbing nature, to the surface, and thus mixing them with the clay, we make use of the best possi-

ble means to render the land fertile. And for the same reason, deep ploughing is useful, when a sandy or calcareous soil rests on a bed of clay.

But deep tillage is by no means equally proper in all soils, indifferently, and under every variety of circumstances. If, for example, a soil be situated over a vein of earth, containing black oxyde of iron, or on a bed of marl, the intermixture of these with it by deep ploughing, would render it for several years almost entirely steril. I have, in my own agricultural operations, tested these results, and speak, therefore, from personal experience.

Adjoining a forest of oaks, on one of my estates, there was a piece of cultivated land, with an argillaceous soil of nearly six inches in depth. Underneath this was a stratum of very dark brown earth, five or six inches in thickness, and consisting of silex, clay, and oxyde of iron. These two different earths I caused to be dug up, and carefully mixed together with the spade. The first year after this operation, the crop was scarcely anything, being much less than before; though the soil had never been very productive. The second year it proved somewhat better; but it was not until the fifth year, that this ground recovered its ordinary fertility.

A friend of mine had a piece of ground that was very moderately productive. The soil being sandy, and very dry, he greatly improved its character by the application of marl, which he suffered to crumble and decompose for two years, before he made use of it. Several fields belonging to the same gentleman were underlaid by a bed of marl at the depth of about twelve inches, and I persuaded him to dig up a plot in one of these, of ten or twelve yards square, and to mix the marl with the top soil, in a larger proportion than he had done before. He did so; and the spot of ground thus treated was almost entirely unproductive for two years; but, after this, it was decidedly more fertile than before.

These two cases were so very striking, that I endeavoured to satisfy myself as to the reasons of the changes thus produced; and which reasons may, I think, be inferred from the properties of the lower strata, at the time of their being mixed with the top soil.

In the case first mentioned, the oxyde of iron which gave a deep brown colour to the stratum, was at its lowest state of oxydation; but, from the moment it was brought in contact with the atmospheric air, it gradually formed new combinations with oxygen, and the earth did not become productive until the iron had been saturated. The colour of the soil was entirely changed during the process of oxydation, from that of black, to a pretty lively and very deep yellow.

Here is a fact, with regard to which, there may be various explanations. Is the oxyde of iron, in its black state, injurious to vegetation? Does this oxyde, in decomposing the air by depriving it of its oxygen, thereby prevent the requisite and salutary action of that fluid upon plants? These are questions, which doubtless require long experience, in order to be satisfactorily answered.

The reasons to be assigned in explanation of the facts in the second case, although not wholly distinct from those in the first, are, still, different. Marl, in general terms, is a compound of the sub-carbonate of lime and alumina; and the different proportions in which these two principles exist together, are the cause of all its varieties. The lime in marl is never saturated with carbonic acid, at the time it is taken from the bed; but, on being exposed to the air, the lime by degrees absorbs the carbonic acid contained in it, until at length it becomes saturated, crumbles to pieces and effloresces. Marl will decompose more rapidly if it be frequently turned, so as successively to expose every part of the lime to the air; and this is generally practised, where it is intended to be used as a manure. We might here propose the same questions

in relation to the imperfect carbonate of lime, as have been already suggested with reference to the oxyde of iron.

Fellenberg, among other experiments for the purpose of settling the principles which he should adopt in the cultivation of his estate of Hofwyl, had his land dug up to the depth of three or four feet, and the result was that it was wholly unproductive for two or three years.

These facts, and many others which I could mention, show that the earths must be saturated with all the principles which they have the power of absorbing from the atmosphere, in order to possess a high degree of fertility. And hence it is that earths, which, in consequence of their depth, have been excluded from the action of the air, cannot become productive, until after they have been exposed to it for a long time. Agriculturists are apprized of this fact, and they thus express themselves in relation to it—that the air deposits its *fructifying principles*, upon the earth; that the soil is not *sufficiently made*, not *ripe enough*, not *aired enough*, &c. These expressions do not, indeed, indicate any very accurate knowledge of the subject; but still it is sufficient to determine the practice.

When, therefore, either by digging or deep ploughing, the unsaturated earths from below have been mixed with the top soil, before being again sowed, it should, at long intervals, be turned over with the plough or mattock. By exposing successively all the different portions of the earth to the action of the air, and of water, they become gradually impregnated with the principles that were wanting; and the same effect is thus produced, as is wrought upon marl, or the black ferruginous earths, by exposing them for a long time to the air, after removal from their beds.

ARTICLE VII.

On the Analysis of Soils.

Although the agriculturist may, by experience and long-continued observation, become at length acquainted with the general character of his soil, and the particular degree of fertility which its different portions possess, still it must frequently be convenient to obtain this information by some more direct and expeditious means.

It is not my intention, however, minutely to describe the processes of an exact and rigorous analysis, since these are for the most part beyond the ability of agriculturists to execute; nor, indeed, is any extreme precision requisite in order to accomplish the object which I have in view.

I shall, therefore, merely point out a few simple methods by which we may acquire a knowledge of the nature and proportions of the principal substances, whether earthy, saline, metallic, vegetable, or animal, which enter into the composition of soils; dwelling on those alone, which are the most essential to their fertility.

In proceeding to analyse an earth, we should take a small portion of it, first mix it thoroughly, by working it with the hand, and then weigh it. It must then be dried, in order to know the weight of water which it contains; and this is done by placing it in some kind of vessel not easily affected by fire, and subjecting it to a degree of heat sufficient to evaporate all the water; keeping it at this temperature for the space of from fourteen to twenty minutes. In order that too great a degree of heat may not be applied, place a small piece of wood on the bottom of the vessel, or stick a few bits of straw in the earth to be experimented with, and take it from the fire the moment that these begin to burn. After this the earth is to be weighed again; and the difference between

its weight now and before, will be equivalent to the weight of water that has been evaporated.

This process will not, indeed, determine, with entire precision, the quantity of water actually contained in the earth, since a portion of it will have been almost solidified by its affinity for some one or more of the earthy principles, either alumina or the salts, or other substances, animal or vegetable, and will be in a state of combination with them; still it will accurately show the whole quantity of water not thus solidified and combined, and all that contributes to moisten the earth.

By experimenting with the different earths dried in this way, at a high degree of temperature, we may readily determine their power of absorbing moisture; and this alone will afford some criterion of their fertility.

After having ascertained what quantity of water, in an uncombined and free state, the specimen here supposed to be used contains, it must be pounded, until it has been reduced to small particles of various degrees of fineness; the gravel and coarser portions are then to be separated from the rest by means of a sieve, and the two different products to be weighed separately, to ascertain the quantity of each. The coarser particles should be analysed by themselves. If they be calcareous, they will dissolve in the acids, and effervesce during the process of solution. To test this, a few of the grains may be thrown into a glass of good vinegar, or of muriatic acid diluted with three or four parts of water; if they entirely dissolve, and especially if the liquid, at the same time, retain its sharp and sour taste, they are then composed altogether of carbonate of lime. It is required that the strongest acids be employed in all such experiments.

When the coarser particles fail to effervesce with acids, they are composed entirely either of silica or of alumina. These two substances may be easily distinguished, since the former is rough to the touch,

scratches glass, and sinks rapidly in water ; while the latter is, on the contrary, smooth and unctuous, and remains for some time suspended in the water. The coarse particles sometimes consist of a mixture of calcareous, siliceous, and aluminous earths, in which cases the acids will always combine with the calcareous portion ; and the acid holding this in solution having been removed, it will readily be perceived, from the properties of the insoluble part remaining at the bottom of the glass, whether it be silica or alumina.

When these coarse particles consist only of quartzous sand or of pure silex, water and the acids have no effect upon them ; but we may easily determine what they are by the characteristics already mentioned, as belonging to silica and alumina.

It is sometimes the case that these particles are more or less mixed with animal or vegetable remains, not wholly decomposed ; but these also may be readily known by the striking properties which distinguish them from fossil substances.

It now only remains to turn our attention to the finer particles which have escaped through the sieve. These consist of the earths, the salts, and portions of animal and vegetable matter in a state of minute division.

To ascertain the nature and proportions of those different principles, the mixture containing them must first be weighed and then boiled, from ten to fifteen minutes, in four times its own weight of water ; after which, the liquid mass should be well stirred, and then left to settle. A deposit will soon be formed, consisting only of the heaviest substances, and generally of a fine siliceous sand : after which, the turbid fluid floating above is to be poured off on to a filter, when the earths and salts, which are the least soluble, will be retained on its surface, while the water, including the remaining part in a state of so-

lution, will flow through into the vessel placed to receive it.

We shall have, then, by this operation, three distinct products; first, the deposit at the bottom of the vessel in which the ebullition has been performed, and consisting chiefly of a very fine sand, composed almost exclusively of silex; secondly, the portion retained on the surface of the filter, being a mixture of the least soluble earths and salts; and lastly, the fluid holding in solution the different salts, and the animal and vegetable substances susceptible of being dissolved in boiling water.

The two first-named products having been carefully dried and weighed, we may proceed at once to their separate examination, with a view to ascertain the nature and proportions of the several substances of which they are composed.

I have already remarked that the first-mentioned product, viz., the deposit, will be composed almost entirely of silica; and, in case it should be otherwise, the fact may easily be detected by the employment of acids, which will not fail to disunite all that is calcareous from the rest; while the insoluble portion remaining is to be subjected to the treatment already pointed out for separating alumina from silica.

As to the second product, viz., that retained by the filter, all that is required for its analysis is muriatic acid diluted with four parts of water. The effect of this acid, on being poured upon the earthy mixture until it ceases to effervesce, is to dissolve the carbonates of lime and magnesia, small quantities of which may be contained in it; and the oxyde of iron is not unfrequently present. This solution being poured upon the filter, such substances as have not been already dissolved will be retained by it, and these, again, must be washed with water until it no longer acquires any taste from them: the residuum is then to be dried and weighed, and it will be found to

consist generally of alumina and a portion of either vegetable or animal matter.

To be sure that the muriatic acid has dissolved the oxyde of iron, it is usual to dip in it a piece of oak-bark; and if it colour it brown or black, it is a certain indication that it contains iron; and, to determine the quantity of this actually present, it is necessary to add prussiate of potash until it ceases to form a blue precipitate. The liquid should then be left to settle; after which the deposit must be collected and heated until it becomes red, when that which remains will be the oxyde of iron, and is to be carefully weighed.

After the iron has been separated from the solution, all that is left in it will be lime, and possibly a little magnesia; and these may be precipitated by means of a solution of carbonate of soda, which is to be poured upon them until there be no longer any deposit: the liquid is then to be turned off, and the residuum washed and dried, when its weight will give the quantity of carbonate of lime contained in the earthy mixture analysed.

If the carbonate of lime and other substances deposited be coloured brown, it is to be presumed that they are mixed either with animal or vegetable matter, the character and proportions of which may be determined by placing them on a piece of red-hot iron, which is to be kept at that temperature over a fire, until their colour becomes white; if the matter contained in them be animal, it will give out the odour of burning leather, hair, or feathers; whereas its smell will be that of wood-smoke, if it be vegetable. These two different substances are often found together; but the process required to determine in what proportions they are combined, is too difficult to be of practical use to the agriculturist, and therefore I shall confine myself to the method just pointed out for merely ascertaining their presence.

The processes here described are simple and easy, and may be performed by any agriculturist the least

instructed. They are not, it is true, altogether exact; but, nevertheless, sufficiently so to furnish results closely approximating to the truth; and to determine, with a good degree of accuracy, the nature and proportions of the different earthy substances which enter into the composition of soils. A more rigid analysis would require the employment of many agents unknown even to most agriculturists, and an amount of scientific knowledge, and of experimental skill, which it cannot be expected that they should possess.

But inasmuch as the salts are highly important agents in vegetation, and all soils are more or less impregnated with them, it would be wrong to omit pointing out a method by which they may be recognised: and, in doing this, I must refer to some definite process.

By boiling a portion of earth, minutely divided, in water, we may separate from it all the soluble salts which it contains; and by afterward evaporating the liquid which holds them in solution, we may ascertain what are their nature and proportions. If the operation be carefully conducted, the salts will be obtained in the form of crystals, and by the properties which distinguish these, their character may be easily determined. Thus nitre, is pungent to the taste, and it ignites upon glowing charcoal; marine salt decrepitates and splits with a cracking noise over the fire; the sulphate of soda puffs up with the heat, gives out an aqueous smoke, and leaves a dry white residuum. When any of these salts are absolutely insoluble, as the phosphate of lime, or soluble with difficulty, as the sulphate of lime (plaster of Paris), the water does not affect them, and they will remain mixed with the earths, without affording any evidence of their presence, by the analysis pointed out. But inasmuch as these substances, and more especially the sulphate of lime, have great influence upon the quality of soils, we should be able to ascertain

their presence; though it should be here remarked, that these salts are commonly contained in soils, in quantities so inconsiderable, as not sensibly to affect the results of the analytical process which has been recommended, for the purpose of determining the nature and proportions of the other more important principles of which they are essentially composed.

To discover whether a soil contains sulphate of lime, (gypsum, plaster of Paris) take a determinate quantity of it, say four hundred grains, mix it with one third as much of powdered charcoal, and subject the mass, for half an hour, in a crucible, to a red heat. Let it then be boiled for the space of a quarter of an hour in half a pint of water; after which the liquid must be filtered, and exposed, for several days, in an open vessel. If a white precipitate be thrown down the soil contains sulphate of lime, and its quantity will be very nearly represented by the weight of the precipitate.—(Davy.)

To ascertain the presence of phosphate of lime, let a portion of the soil be digested in an excess of muriatic acid; the solution should be then evaporated to dryness, and the residuum having been washed in plenty of water, the insoluble phosphate will remain exposed.

CHAPTER IV.

Of the Nature and Action of Manures.

[FROM CHAPTAL'S CHYMISTRY APPLIED TO AGRICULTURE.]

UNDER the general name of manures may be included all those substances, which, whether deposited in the soil, or existing in the atmosphere, are capable of being absorbed by the organs of plants, and of

ministering to their nourishment and growth; and portions of which are furnished by each of the three kingdoms of nature. It is, however, mostly decomposed vegetable remains, and certain of the parts and products of animals, which are ordinarily employed as manures. The salts likewise act as such; being filtered by passing through the fine network of plants, they enter into their composition, and stimulate vegetation.

It would, however, be giving too great an extent to the term, if we should, for our present purpose, include all these different substances under the general name of manures. I shall, therefore, in the present treatise, consider manures as consisting of two kinds; and adopting, as far as possible, the language in common use, I shall call those *nutritive manures*, which afford to plants their nourishment, and all those, *stimulating manures*, which serve merely to excite their organs of digestion. These last, indeed, are to be considered as the condiment, or seasoning spices, rather than the food of plants.

ARTICLE I.

Of Nutritive Manures.

The nutritive manures are those which contain such juices or substances as are soluble in water, or which, by their being very minutely divided, may be carried along in connexion with it; and all the vegetable and animal juices are of this character.

But these alimentary substances are rarely employed in their natural state; it being thought better that, before being used, they should be left to rot or ferment; and for the following plain reasons. By the process of fermentation all these substances are decomposed, and rendered more easily soluble in water; and it is attended, besides this, with the further advantage, that different gases, as carbonic acid, carburetted hydrogen, nitrogen, and ammonia, are disengaged by it,

and either serve directly for the food of plants, or as healthy stimulants to their organs of digestion. Care is, however, necessary that the decomposing process be not continued too long; for if it be suffered to go on until it is complete, nothing will be found remaining, except the fixed salts, along with such earths and juices as have resisted its action. When manures have been thus entirely decomposed, their effect is little more than momentary, benefiting only a single crop; whereas if they be applied before they have reached this ultimate state, their influence will be felt for several years. The decomposition being retarded in this latter case, in consequence of the manure being separated into minute portions, goes on only very gradually in the earth, and thus it will continue, for a long time, to furnish aliment to plants.

The excrement of animals, all of which is derived from the digestion of their food, has already undergone a partial decomposition, by which the alimentary substances have become disorganized, and their nature more or less changed. The different power of the digestive organs in the various species of animals, and dissimilarity in their food and in the character of the digestive fluids furnished by their stomachs, produce considerable modifications in these manures.

The excrementitious matter of some animals, as of pigeons, fowls, &c., is made use of without moisture, or being subjected to any new fermentation, for the reason that it contains a large proportion of salts, and but few juices. Grounds are often manured with the fresh dung of sheep, which has been collected in the folds, or which, together with their urine, has been deposited by the animals themselves while feeding in the fields; but that of horses and of horned cattle is generally left to undergo another fermentation, before being used for manure.

The method most generally adopted to effect this further elaboration of the animal manures, is, in the first place, to form in the stall or sheepfold a bed either

of straw or of dried leaves. Upon this is thrown the dung of the quadrupeds, and the mass is moistened with their urine. At the end of fifteen days, or, at most, a month, this heap is removed to some place suitable for its fermentation, and there formed anew; care being taken that the litter and the leavings of the racks are daily spread upon it.

A further advantage attending this plan of fermentation is, that it keeps the stables wholesome, and the animals cleanly. When, owing to a scarcity of straw, the beds cannot be made of sufficient thickness, or renewed as often as they should be, heaps of rubbish, such as old plaster, mortar, &c., broken fine, may be formed, and a thin covering of straw spread over them. The substances composing these heaps will retain the urine, and, when sufficiently impregnated with it, may themselves be employed as manures. The nature of the substances thus employed should vary, according to the character of the soils to which they are to be applied; as by this means they may be made to serve the purpose of correctives as well as manures. Thus, for clayey and compact soils, it is proper to reserve such heaps as consist of the remains of old lime mortars, while others which contain fat marl, or argillaceous mud, are more suitable for light and dry soils.

In some countries, where agriculture is skilfully conducted, the ground of the stables is paved, and made slightly descending, that the urine may pass off into reservoirs prepared to receive it, and in which it is left for some time, along with different animal and vegetable substances, to ferment; after which it is made use of to water the fields, during the first stages of vegetation.

The art of fermenting manures with litter is still very imperfectly understood in some parts of France. While in one place they are left to rot until the straw is entirely decomposed, in another they are taken to the fields in the same state in which they are removed

from the stables. Both of these practices are equally erroneous. By the first, nearly all the gases are dissipated and lost, and the nutritive juices decomposed; and by the latter, fermentation, which cannot be carried on effectually except in large masses, will proceed but very slowly and imperfectly in the fields, and that portion only of the manure which mixes with the water by simple washing, will be conveyed by it to the plants.

There is, perhaps, nothing which is more important in agriculture, or which requires greater care, than the proper preparation of manures. In the conducting of this process, various chymical principles are involved, which, without going into their explanation, I shall simply point out; since it will be sufficient for the purposes of the agriculturist, that he is furnished with the rules by which he should direct his practice, without requiring of him any extensive acquaintance with the sciences, which are auxiliary to his own.

1. Solid substances, whether vegetable, animal, or mineral, cannot be introduced into the organs of plants, except in a state of solution with water,* or when

* The pores in the fibres of the roots of plants are so small, that it is with difficulty they can be discovered by the microscope; it is not, therefore, probable that solid substances can pass into them from the soil. I tried an experiment on this subject: some impalpable powdered charcoal, procured by washing gunpowder, and dissipating the sulphur by heat, was placed in a vial containing pure water, in which a plant of peppermint was growing: the roots of the plants were pretty generally in contact with the charcoal. The experiment was made in the beginning of May, 1805. The growth of the plant was very vigorous during a fortnight, when it was taken out of the vial. The roots were cut through in different parts; but no carbonaceous matter could be discovered in them, nor were the smallest fibrils blackened by charcoal, though this must have been the case had the charcoal been absorbed in a solid form.

No substance is more necessary to plants than carbonaceous matter; and if this cannot be introduced into the organs of plants except in a state of solution, there is every reason to

they are so minutely divided as to be carried along by adhering to that fluid.

2. Vegetable and animal substances which are, themselves, insoluble in water, by being decomposed, form other compounds which are soluble, and thereby in a state to furnish aliment to plants.

3. Vegetable and animal substances, after their soluble portions have been removed by the action of water, may, in the process of their decomposition, still form new compounds, which shall be capable of solution. Of this, I have furnished examples, in treating of vegetable mould.

That which makes the preparation of manures in the most profitable manner a subject of no little difficulty is, that whatever method we may adopt, there will still be a loss of some portion of their nutritive principles. Even when manure and litter are carried to the fields in an entirely fresh and unfermented state, and mixed immediately with the soil, although, by this means, the salts and soluble juices which they contain are all preserved, to be converted to the uses of vegetation, still the fibre, the unctuous matter, the oils, &c. remain in a great measure inert in the soil, and their subsequent decomposition will be very slow and imperfect. If, again, in reverse of this, the manure be collected in heaps in the farm-yard, it speedily becomes heated, carbonic acid gas, and then successively carburetted hydrogen, ammonia, nitrogen, &c., in great quantities, are evolved, and these substances are entirely lost to vegetation. A brown liquid, the colour of which becomes more and more dark, moistens the mass, and flows upon the ground about it; every portion is gradually disorganized, and when at length the fermentation is complete, there is left only a residue consisting of earthy and saline matter, mixed with a small quantity of blackened fibre, and charcoal in the state of powder.

suppose that other substances less essential will be in the same case.—*Davy's El. Ag. Chym.* pp. 249, 250.

It is not generally the case, that fermentation is suffered to go on to this last stage of decomposition; nevertheless, as it is ordinarily conducted, a very large proportion of the nutritive properties of manures is lost.

The most common practice is to throw the dung and litter, as they are removed from the stables and sheepfolds, into a heap together, in the farmyard, and to let them remain there and ferment, until the putting in of the crops, in spring or autumn, requires that they be taken to the fields.

This method is attended with very serious disadvantages. And first, in consequence of portions of the manure being deposited at different times, it undergoes very unequal degrees of fermentation, one part being subjected to the process for six months, and another for not exceeding, perhaps, fifteen days; secondly, the manure being soaked and washed by frequent rains, becomes deprived of all the salts and soluble juices which it contains; thirdly, the extractive matter, mucilage, albumen, and gelatine, in the lower and central parts of the heap, become completely decomposed; and finally, the gases, which are an important aid to vegetation, when developed near the roots of plants, escape into the air. Davy states, in relation to these last, that by causing them to be disengaged under the roots of a portion of turf in his garden, the vegetation became far more luxuriant than that of the turf adjoining.

And now from what has been said, the inquiry naturally presents itself whether it be better, on the whole, that manures should be fermented, or employed in an entirely fresh and undecomposed state; and, this will lead us briefly to consider the nature of manures, since without a knowledge of their different properties, the question here proposed cannot be satisfactorily answered.

The principal vegetable substances made use of for manures contain mucilage, gelatine, oils, sugar, starch,

extractive matter, and frequently albumen, acids, salts, etc., together with a large quantity of fibrous matter, insoluble in water.

The various substances afforded by animals for the same purpose, including their dung and other excretions, are gelatine, fibrine, mucus, fat, albumen, urea, uric, and phosphoric acid, and some salts.

Most of these different substances, both animal and vegetable, are soluble in water, and may, in this state, be employed as manure without any previous fermentation; but whenever they contain a large proportion of insoluble matter, it then becomes necessary that they be decomposed by fermentation; since by passing through this process their nature becomes changed, and they form new compounds, which are capable of solution, and, consequently, of being introduced into the organs of plants.

Gay-Lussac and Thenard, by analysing woody fibre, obtained oxygen, hydrogen, and a much larger quantity of carbon than is contained in the other parts of plants; and they have determined the proportions of these different substances. Now it is well known that fermentation carries off abundance of carbon; and consequently it is evident that, by subjecting vegetable fibre to this process, it will gradually be deprived of the principle which chiefly constitutes its distinctive character, until at length it becomes entirely soluble in water. It is by this means that ligneous plants and dry leaves are converted into manures.

Since all the hard parts of plants contain fibre, which can be rendered soluble in water, only by long-continued fermentation; and since, also, it is in the fibre that carbon, so essential to vegetation, principally exists, it follows that fermentation is indispensably necessary, in order to obtain from plants such portions of them as are most valuable for manures.

But it may, perhaps, be urged in objection to the views here advanced, that crops in a green state are ploughed directly into the ground, and that the prac-

tice is manifestly attended with great advantage; in answer to which I must observe, that the plants are, in this case, buried in the soil at the time they are in flower, when they are in a pulpy state, and their fibre soft and but imperfectly formed, so that the heat and moisture of the earth are sufficient to decompose them; and that this would not take place if they were, on the other hand, dry, and exhausted of their juices by the formation of seed.

The dung of animals, when by itself, may indeed be turned into the soil, as it is taken from the stable without disadvantage; and I am even of the opinion that this is the best way to make use of it; but if it be mixed with litter, I consider it preferable to subject the whole to a slight fermentation, the more readily to convert the straw and the leaves into manure.

To avoid the inconveniences inseparable from the method usually practised in conducting this operation, certain precautions must be observed.

The dung and litter, instead of being accumulated in large heaps, and left to rot under exposure to all the vicissitudes of the weather, should be deposited in some sheltered situation, as under a shed, or even a simple roof of straw or heath.

A heap should be formed, by itself, of each successive clearing of the stables, cattle-stalls, and sheep-folds. These heaps should be from eighteen inches to two feet in thickness; and as soon as they begin to smoke, or the heat in their centre rises to more than ninety-five degrees Fahrenheit, they should be turned, to prevent too rapid decomposition.

Fermentation should be stopped, whenever the straw begins to be of a brown colour, and the firmness of its texture is destroyed; and to effect this, the top of the heap may be thrown to the sides, and its depth diminished, to check the fermentation; or, if the manure be wanted at the time, it may be applied immediately to the soil; or, which will answer the purpose of retard-

ing its farther decomposition, it may be mixed with vegetable mould, old plaster, sod, rubbish, etc.

When the dung of animals has but little consistence, as is the case with that of neat-cattle, in spring and autumn, it should, as I have already recommended, be made use of immediately; and if it cannot be applied at once to the soil, it should then be mixed with earths and other substances of a dry and porous nature, and which may be usefully employed as correctives for soils deficient in the properties which these contain.

On nearly all our farms, the manure is thrown from the stables into the open air, and there left entirely unprotected from the weather; and the consequence is, that the rains, by frequent washings, carry off with them the salts, the urine, and the soluble juices, of which they form little streams of a blackish colour around the heaps, and thus the most fertilizing principles of the manure are entirely lost. In the further progress of fermentation, new combinations of a soluble nature are successively formed, and these, in their turn, are also carried away; so that, one after another, all the nutritive and stimulating principles of the manure disappear, until at length its weakest and least valuable portion alone, mixed with bits of worthless straw, is all that remains.

To prevent, in some degree, a waste so detrimental to agriculture, a deep trench at least might be dug, to receive and retain all the juices which flow from the dung-heap, in order that this fertilizing liquid might be applied either to the crops of grain, or to the meadows in the spring; or that it might be reserved to irrigate the latter after the first mowing. A large cask placed upon a small cart, and which may be filled by means of a hand-pump, is all that is required for this purpose. Under the spigot should be fixed a narrow trough about four feet long, and its bottom pierced with holes to scatter the fluid.

This kind of watering, when it is practised after

mowing, has a surprising effect upon the crop of the following year.

In deciding the question whether it is best or not to subject manures, consisting of a mixture of dung and litter, to fermentation, we must have regard to the nature of the soils for which they are intended to be used. When these are clayey, compact, and cold, unfermented long manure is undoubtedly the most suitable; since, in this state, it has the following capital effects; first, to correct the faulty condition of the soil, by rendering it looser, and more accessible to the air and to water; and secondly, to warm it with the heat which it constantly gives out, in the progress of its fermentation and decomposition. If, on the other hand, the soil be of a calcareous nature, light, open, and warm, then short-fermented manure is best, since it will heat it less; and in place of making the earth, already too porous, still more loose, and thereby more permeable by water, it will tend to impede the flow of that fluid through it. These facts are known to observing agriculturists, from practical experience.

When we are about to apply manures to particular kinds of soil, we should, in our selection of them, be governed by a careful observation of their nature and effects. The dung of sheep possesses the most heating qualities, and next that of horses; while that of neat-cattle is the least heating of any.

Animal substances of a soft and fluid nature undergo changes the most readily; and their decomposition is rapid in proportion as they contain a less quantity of earthy salts. During the process of putrefaction, they give out abundance of ammoniacal gas; and this circumstance distinguishes them from vegetable substances, the decomposition of which does not produce this gas, any farther than as they contain a small portion of albumen. It is more particularly to the development of this gas, and its introduction into plants, in combination with gelatine, that we may refer the

wonderful effects, as we shall presently see, of certain dry animal substances upon vegetation.

Next to the several kinds of which we have already spoken, the urine of horned cattle and of horses affords the most abundant manure, which can be obtained for the uses of agriculture; and it is not without regret that one daily witnesses how little pains is taken to save it. I have previously stated that in those countries, where agriculture is in the most flourishing condition, and conducted upon the most enlightened principles, the stable floors are all paved, and formed with a gentle slope; by which means the urine of the animals passes off into reservoirs, where it is collected, and into which are thrown rape and flax-seed cakes, colewort, and a variety both of animal and vegetable substances to steep and ferment. As soon as vegetation begins to start in the spring, this fermented liquid is removed to the fields to water the crops.

There are few animal substances, the constituent principles of which vary so much as those of urine. Great changes are produced in it by different kinds of food, and by the particular state of health of animals. It is more or less copious, and possessed of nutritive and stimulating properties, in proportion as the substances on which these subsist, are succulent or dry, those living upon hay and other dried fodder affording it in less quantity, than others which are fed with green herbage; though in the former case it is more abundantly charged with salts, than in the latter. That voided immediately after drinking, has less of animal matter, than when it has been gradually secreted from the blood by the urinary organs.

It is doubtless owing to these different circumstances, as affecting individual animals, that there has been so little of agreement in the results of the numerous analyses which have been made of this liquid.

According to Brandt, the urine of the cow yielded on analysis:—

Water	65
Phosphate of lime	5
Muriate of potash and of ammonia	15
Sulphate of potash	6
Carbonate of potash and of ammonia	4
Urea	5
	100

Fourcroy and Vauquelin obtained from that of the horse:—

Carbonate of lime	11
Carbonate of potash	9
Benzoate of soda	24
Muriate of potash	9
Urea	7
Water and mucilage	940
	1000

Human urine analysed by Barzelius afforded:—

Water	933
Urea	30.1
Uric acid	1
Muriate of ammonia, free lactic acid, lactate of ammonia and animal matter	17.4
	981.5

The remaining $\frac{18.5}{1000}$ parts consisted of phosphates, sulphates, and muriates.

It appears from these analyses that the urine of different animals, varies greatly in the nature and proportions of its constituent principles, but that it all contains salts which may be introduced into plants, by means of water holding them in solution, as well as the animal portions and the urea, which are easily soluble, and decompose readily.

Among the ingredients contained in urine, there are some which the organs of plants are incapable of decomposing, as the phosphates of lime, and the muri-

ates and sulphates of potash ; and these can be useful to vegetation only by their stimulating and detergent power. But the urea, mucilage, uric acid, and other animal substances which enter into its composition, are, doubtless, eminently nutritive.

This liquid should never be employed as a manure, in the state in which it is produced ; since it acts too powerfully, and there is danger of its withering the plants to which it is applied. It should, therefore, either be diluted with water, or left to ferment for a while, before being used.

Urine answers a valuable purpose in moistening the different substances collected for the formation of composts, by increasing their fertilizing properties ; and by facilitating the fermentation of such of them as require to be decomposed, in order to develop their nutritive powers.

Urine is also combined with plaster, lime, &c. ; and in this connexion it forms a manure of great activity, admirably adapted to cold soils.

Bones are, at the present day, employed by agriculturists with great success in fertilizing the soil. These parts of animals consist principally of phosphate of lime, and gelatine ; the kinds of bones generally made use of containing nearly equal quantities of each. Those of the ox afford, by analysis, from fifty to fifty-five per cent. of gelatine ; the bones of the horse give from thirty-six to forty ; and those of swine from forty-eight to fifty.

Gelatine is more abundant in the bones of young animals, and in such, generally, as are less solid and compact. The feet bones of the elk, the stag, the roebuck, and the hare, yield, on analysis, from eighty to ninety per cent. of phosphate.

Before using bones as a manure, they must be finely ground, and then left for some time in a mass together, until they begin to ferment. As soon as the heat begins to give out a pungent odour, it should be opened to arrest further fermentation ; and its materials may

then either be spread on the soil to be turned in with the plough, or scattered on the seed grain to be covered at the same time with it. When seed is sown singly in furrows, a portion of bone-dust may be advantageously strowed in the furrows with it.

It is a common practice, in some countries, to separate the fat, and a large proportion of the gelatine from bone-dust, by means of boiling water, before selling it to the farmers; an operation, however, which renders it comparatively worthless, by depriving it of its most fertilizing properties.

In watching carefully the appearances of bone-dust in a state of fermentation, I have noticed that portions of its surface were covered with a thin coating of unctuous matter, acrid and pungent to the taste, and which appeared to me to consist of a combination of gelatine and ammonia; the latter of which is always disengaged in the decomposition of animal substances. This opinion I find supported by the observations of d'Arcet, to whom we are indebted for a very valuable treatise on gelatine.

In those cases where bone-dust is made use of without having been previously subjected to incipient fermentation, it is possible that the gelatine may be slowly decomposed in the earth, and, in time, produce the same result. Water, indeed, by acting upon it, may gradually dissolve its gelatine, and convey it to the plant. But, in whatever light we consider it, this material has, undoubtedly, highly fertilizing properties, both as a purely nutritive manure, and as being an active stimulant at the same time.

Bones, on being calcined in a close vessel, give out oil and carbonate of ammonia; the phosphate which they contain is not sensibly diminished, but their gelatine is decomposed; and they lose from thirty to thirty-two per cent. of their weight, by the operation. The portion which remains, by being ground and pulverized, may be used with great advantage in the process of sugar refining; and after having been em-

ployed for this purpose, from its being saturated with bullocks' blood and animal carbon, I have found it to be one of the best manures that can be applied to artificial meadows, as those of clover and trefoil. It should be scattered with the hand over the fields, at the starting of vegetation in the spring.

Certain other dry parts of animals, as the horns and hoofs, are very similar to bones, as it regards the nature of their constituent principles; but the proportions of these vary very greatly in different animals. Gelatine predominates in them all; and it is for this reason that they are even more valuable than bones, as a manure. Merat Guillot could obtain no more than twenty-seven per cent. of phosphate of lime from the horn of the stag; and Hatchett, in analysing five hundred grains of that of the ox, procured only one fifth part of earthy residuum, nearly one half of which was phosphate of lime.

The clippings and scrapings of horn make an excellent manure; and, since water does not easily penetrate them, and they have but little tendency to ferment, their effect is prolonged for a considerable number of years.

The refuse of wool may likewise be very usefully employed as a manure. It appears from the ingenious experiments of Hatchett, that hair, feathers, and wool, are formed by a very peculiar combination of gelatine with a substance resembling albumen; they are only very gradually dissolved by water, aided by a process of fermentation, which is slow in taking place, and which continues for a long time.

An instance of luxuriant vegetation, one of the most wonderful which I have ever seen, is that of a field in the environs of Montpellier, belonging to a manufacturer of woollen blankets. The proprietor applies to it annually the sweepings of his workshops; and the crops, both of grain and fodder, which this piece of land produces, are truly astonishing.

It is well known that wool emits a fluid, which

hardens upon its surface, and which is, nevertheless, easily soluble in water; from its oily nature it is called grease. The water in which wool has been washed, contains abundance of this substance, and makes an excellent manure. About thirty years ago, I was acquainted with a wool merchant of Montpellier, who had his washing place in the midst of a field, a great part of which had been converted into a garden. The only water which he applied to his vegetables, was that in which the wool had been washed; and such was the luxuriance and beauty of his plants, that everybody came to admire them. The Genoese carefully collect, in the south of France, all the shreds and remains of woollen cloths which they can pick up, and place them to rot about the foot of their olive trees.

According to the analysis of Vauquelin, the grease of wool is a saponaceous substance, the base of which is potash, with an excess of oleagenous matter; it also contains acetate of potash, a small quantity of the carbonate and of the muriate of the same base, and an odorous oily substance.

The dung of birds is likewise a very active manure. It differs from that of quadrupeds, in the food from which it is derived being more perfectly digested, in its containing more of animal matter, and of salts, and some of the principles found in the urine of quadrupeds.

The dung of the numberless sea-fowls in the islands of the Pacific (which forms a considerable article of traffic with the neighbouring continent of South America, fifty ship loads of it, according to Humboldt, being annually imported into Peru) contains, besides, a large quantity of uric acid, partially saturated with ammonia, and potash, the phosphates also of lime, ammonia, and potash, and a portion of unctuous matter. Davy discovered uric acid in the dung of the cormorant.

From experience of its fertilising effects, pigeon

dung is carefully collected in France. Davy found one hundred parts of it, when fresh, to contain twenty-five parts of matter, soluble in water; whereas the same quantity, after having undergone putrefaction, yielded only eight; whence this distinguished chymist very properly concluded, that it should be used before fermentation. This manure is of a heating nature, and may be strewed on ploughed ground with the hand, before covering the seed; or it may be applied to strong soils in the spring, when vegetation appears to languish.

The dung of barndoor fowls is very similar to that of pigeons, but is not as strong; it contains, likewise, a portion of uric acid, and may be used in the same way as the other.

In the south of France, where the silk culture is extensively pursued, they make very great use of the larvæ of the worms, after the silk has been reeled from the cocoons. These they strew about the foot of their mulberry or other trees, that may be in a drooping condition; and this inconsiderable portion of manure revives them astonishingly. I have distilled some of these larvæ, and in no other animal substance have I ever found so much ammonia.

Night soil is a very powerful manure; but farmers make little account of it, because, in its natural state, it is too stimulating; and they neither understand how to diminish its activity, nor to apply it in its various stages of fermentation, to the peculiar wants of the different species of vegetables.

In Belgium, which may be considered as the cradle of enlightened agriculture, and where judicious modes of culture are perpetuated, and constantly improved, they collect astonishing quantities of this manure; which is employed, during the first year of its fermentation, in the cultivation of oleagenous plants, hemp and flax; and in the second, for crops of grain. They also let it steep in water or urine, and with the liquid part they irrigate their fields in the spring, at the first

appearance of vegetation. It is likewise dried, and, in this state, strewed on fields of cabbage.

The Flemings think so much of this manure, that the cities farm out, at a very high rate, the privilege of collecting and disposing of it; and there are sworn commissioners whose business it is to attend to the sale. These officers understand the particular degree of fermentation which is suited to the several kinds of plants, and to the different periods of their growth.

In France there is a difficulty in bringing this branch of husbandry to the high state of perfection which it has attained in Belgium, for the reason that our farmers are not aware of its importance, and have, moreover, an aversion to the use of this kind of manure. But would it not be much better carefully to collect all these matters, mix them with lime, plaster, rubbish, &c., and when their odour by this means has been dispelled, to employ them for the improvement of the soil?

Already, in most of our large cities, these substances are obtained for the purpose of being converted into poudrette; and this pulverized product is in great request with our agriculturists, from their experience of its fertilizing effects. May we not hope that, when they shall become still more enlightened, they will make use of the feculent matter itself, as being more highly charged with nutritive principles, and equally abounding in salts. There is no difficulty in controlling and modifying its action, by means of fermentation, or, which is a still better way, by mixing it with plaster, earth, and other absorbents, to deprive it of its odour.

As the soil derives its fertility from manure, a good farmer will employ all possible means to procure it. This should be with him a primary object, and his daily care; for without manure, he can have no compensating harvest. The scarcity of manure, or, in other words, the bad condition of the crops, is, in a great measure, owing to the prejudices which so gen-

erally control the farmer; and to the blind adherence to usage, by which he is directed in all his labours. His knowledge extends merely to the particular kinds of straw, which are supposed to be most proper for manure; and these, in a heap of litter, he considers as constituting the most valuable part; whereas, in reality, they form but a very small proportion of its fertilizing properties.

According to the experiments of Davy, the straw of barley contains not quite two per cent. of matter soluble in water, and which has some trifling analogy to mucilage; that of wheat scarcely contains one and a fourth per cent. of similar matter; while the residue in both consists entirely of a fibrous substance, which, even under circumstances the most favourable, is exceedingly slow in decomposing.

I am fully persuaded that there is not a substance in the whole vegetable kingdom, which furnishes so little nutriment as the dry straw of the cereal plants. It is as little worth to animals as to vegetation; doing little more than to distend the stomachs of the former, while, for the support of the latter, it affords merely one hundredth part of its own weight in soluble manure.

Weeds, the leaves of trees, and the different succulent plants which grow so abundantly in and about ditches, on waste lands, and by the sides of roads and fences, if cut or pulled at the time when they are in flower, and slightly fermented, will yield from twenty to twenty-five per cent. more manure than straw. These plants, by being carefully collected, would be of immense use to the agriculturist; and in addition to the manure obtained from them, he would realize from their extirpation this further advantage, that their seeds would not be scattered far and wide to spring up, and exhaust, and foul his land.

The sod also by the wayside, and on the borders of enclosures, may be used for the same object. It should be taken up with the roots and the earth to-

gether, and after being sufficiently rotted, by lying some considerable time in a heap, it may be removed to the field, or, which is a still better method, it may be cut, and, when sufficiently dry, burnt, and the product of the combustion spread as a top-dressing for the soil.

Only that straw serves as a litter for animals, and thus contributes to their cleanliness and health; and but that it becomes impregnated with their dung and urine by such use of it, it would be better to cut off the spikes of the grain alone, and to leave the stems in the field, since these latter act merely as absorbents of what is really manure.

We hear it constantly said that, in addition to its nutritive properties, long manure possesses the advantage of separating the parts of compact soils, so that they are more easily penetrated by air and water. This is undoubtedly true; and I am ready to admit further, that it acts in this manner almost exclusively through the straw which it contains; but then these benefits might all be secured, by turning in the straw on the spot, without the trouble and expense of removing it from the field.

Besides affording food to plants, manures have other qualities which add essentially to their fertilizing power. In the state in which they are employed for agricultural purposes, they are never so entirely decomposed but that they still continue to ferment. Their effect, therefore, is to maintain in the soil a degree of humid warmth, which is highly propitious to vegetation, and which greatly protects plants against the injuries which they might otherwise experience from sudden changes of atmospheric temperature.

Manures contain, also, certain viscous fluids, which render them very slow in drying, when not in contact with the air; and, owing to which, they tend to keep the roots of plants moist, and thus to support the latter when, but for this, they might perish from

drought. There are likewise contained in manures a greater or less quantity of salts, which, being soluble in water, are conveyed by it to plants, and serve to stimulate their organs and excite them to vigorous and healthy action.

When manures are mixed with earth, they should, in this state, be considered also as correctives, and should be adapted to the nature of the particular soils, for the amendment of which they are designed. Soils of a compact texture require segregation of their parts and warmth; and for such long manures, which have been but slightly fermented, and those especially which contain abundance of salts, are best adapted. Calcareous and open soils generally, need manures of an unctuous nature, which decompose only very gradually, and the effect of which is to combine the disunited particles together, so that they shall longer retain moisture for the use of plants during seasons of drought.

By observing these principles, we shall succeed in assigning to each particular kind of soil and plant their appropriate manure. The attention of agriculturists is already occupied with this subject, in the formation of mixed manures, known under the name of *composts*. These are prepared by placing different kinds of manure, in a heap together, in separate layers, taking care, in the meantime, to correct the faults existing in some by properties peculiar to others, so as to give to the mixture generally, a character which will adapt it to the soil to which it is intended to be applied.

If, for example, we propose to form a compost suited to a clayey and compact soil, our first stratum should consist of old plaster, rubbish, and the mortar of demolished buildings: this may be covered with the dung and litter of horses and sheep; another stratum should be added composed of the sweepings of the yards, passage-ways, and barns; also of lean marl, of a dry and calcareous nature, the mud of riv-

ers, feculent substances collected on the farm, remains of hay, straw, &c.; and on this, again, should be deposited a stratum of the same materials as those composing the first.

Fermentation will take place immediately in the strata containing the dung, and the liquid flowing from these will mingle with the materials of the other strata. As soon as it is perceived, by the signal already described, that decomposition has advanced far enough, the heap should be taken down, and when the various substances of which it consists, have been thoroughly mixed together, the whole will be ready for immediate use.

If, on the other hand, you would prepare a compost for a light, porous, and calcareous soil, it should consist of materials of an entirely different character. In this case the argillaceous principles, substances of a compact texture, and manures the least heating, should predominate; and fermentation should be suffered to go on, until the feculent portion be reduced to a yielding, glutinous paste. The earths employed in this compost should be of a clayey nature, partially burnt and beaten small, fat argillaceous marls, and the mud of ponds and marshes.

By adhering to these principles, I have completely succeeded in changing the character of a steril soil, in the neighbourhood of one of my manufacturing establishments. The soil here alluded to was composed of calcareous earth and light sand; and, for several years in succession, I caused to be spread upon it a portion of calcined argillaceous earth; and now this same soil, on which formerly a few kinds of stone fruit only would grow, has become admirably adapted to the production of fruits generally; and, instead of yielding, as before, meager crops of oats and rye merely, it bears, at present, excellent wheat.

ARTICLE II.

Of Stimulating Manures.

Lime.—In the preceding article, we have treated of manures as containing in combination with the alimentary principles necessary to vegetation, certain stimulating salts inseparable from them, and which by solution pass into the organs of plants, and thus excite in them a healthy and vigorous action. But, since these latter principles differ essentially from the first in their mode of operation, and in their uses in the vegetable economy, and are moreover frequently employed by themselves, to quicken and invigorate vegetation, it is necessary that I should speak of them separately, and in a more particular manner.

From very careful and exact experiments made by de Saussure on the different substances which constitute the nutriment of plants, it would appear that the roots absorb their various salts and extracts in a state of solution in water; and that the absorption of hurtful salts is facilitated, and rendered more abundant, by the languishing and unhealthy condition of plants.

We may infer then, from this latter principle, that the absorption of the juices and salts by plants is by no means a mere passive and physical faculty; but that, on the contrary, it is directed by certain laws of vitality by which they are governed in a living state. It is only when the force of these laws is weakened by a feeble and sickly condition of the plant, that external agents have the power to act upon it in a manner more absolute and uncontrolled than before. Plants do not imbibe indifferently, or in equal quantities, all the different substances which may be in a state of solution in water; but manifest a preference for those which are the least viscid among them.

We conclude, therefore, from these premises, that

healthy plants are not altogether passive with regard to the reception of their food, but that, to some extent, they have their tastes and preferences in relation to it; the physical laws predominating over those of its vital organization, only when the plant is in a less sound and vigorous condition.

All the parts of plants, whether soft or fibrous, are evidently the product of the juices and gases which have been elaborated in their organs, and appropriated to their nourishment. The saline substances found in them are such as have been derived from the soil, and have undergone no alteration.

Varied as are the products of the vegetable kingdom, the elements of which they consist are few in number. All that we find in any of them is oxygen, carbon, hydrogen and nitrogen, combined in dissimilar proportions; a variation of a few hundredths more or less in the proportions of these elements, often occasioning a surprising difference in the character of vegetable products. And hence it is, that the slightest derangement of the organs of plants causes the formation of new compounds, wholly unlike those which had previously been produced.

It is universally admitted that the juices, the oils, the resins, the fibre, and all the parts essentially vegetable, are formed by the action of the organs of the plant; and that the elements of these compounds are those of the bodies by which it is nourished, and which it combines in a manner peculiar to itself, and suited to its particular organization. Nor is there anything resembling creation in all this; but simply decomposition in the first instance, and afterward a new combination of the elements in altered proportions.

There are naturalists, indeed, in other respects highly deserving of credit, who pretend to assert that plants themselves, by the mere act of vegetation, actually form salts and earths. But as science has advanced and become more exact, it is perceived that

no one experiment which they have cited in support of this doctrine, is of a character to be relied upon. Some of these philosophers have applied to their plants distilled water, while others have had them to grow in washed sand; and, in nearly every instance, the air has been permitted to come freely to them. Several have analysed, with a greater or less degree of care, the soil in which the plants grew; and nearly all have concluded that the salts and earths found in them, and the existence of which, or at least of the same quantity, in the substances by which they had been nourished, could not be demonstrated, that therefore these salts and earths must have been the work of the plants themselves. But is not the atmosphere, so continually agitated, unceasingly displacing and renewing the salts and earths which it deposits upon plants? The fine dust which it carries along with it, are not its soiling effects perceived in places the most remote and elevated? And water, be it ever so carefully distilled, when submitted to the action of the galvanic battery, is found to contain, as has been shown by the admirable experiments of Davy, minute particles of alkali and of earth.

Schrader and Braconnot have published the results of their experiments; and they have been induced by these to suppose that salts and earths are actually created in the organs of plants; but Lassaigne has proved that the developed plant affords precisely the same salts and earths as those contained in the parent seed from which it is derived.

Th. de Saussure, whose opinion is of great weight on such subjects, has demonstrated that plants, in no case, create any of these substances.

If, again, the formation of certain kind of salts be, in truth, an attribute of the plant itself, why is it that *salsola* fails to yield marine salt, whenever it grows not on the shores of the sea? Why, under similar circumstances, does the *tamarisc* afford no more of sulphate of soda? And why, in short, is the *turnsol*

destitute of saltpetre, when it vegetates in a soil which does not contain it.*

But be this doctrine as it may, the following prac-

* Some inquirers, adopting that sublime generalization of the ancient philosophers that matter is the same in essence, and that the different substances considered as elements by chymists are merely different arrangements of the same indestructible particles, have endeavoured to prove that all the varieties of the principles found in plants may be formed from the substances in the atmosphere; and that vegetable life is a process in which bodies that the analytical philosopher is unable to change or to form, are constantly composed and decomposed. These opinions have not been advanced merely as hypotheses; attempts have been made to support them by experiments. M. Schrader and Mr. Braconnot from a series of distinct investigations, have arrived at the same conclusions. They state that different seeds sown in fine sand, sulphur, and metallic oxydes, and supplied only with atmospheric air and water, produce healthy plants, which by analysis yielded various earthy and saline matters, which either were not contained in the seeds or the material in which they grew, or which were contained only in much smaller quantities in the seeds: and hence they conclude that they must have been formed from air or water, in consequence of the agencies of the living organs of the plant.

The researches of these two gentlemen were conducted with much ingenuity and address; but there were circumstances which interfered with their results, which they could not have known, as at the time their labours were published they had not been investigated.

I have found that common distilled water is far from being free from saline impregnations. In analysing it by voltaic electricity, I procured from it alkalies and earths; and many of the combinations of metals with chlorine are extremely volatile substances. When distilled water is supplied in an unlimited manner to plants, it may furnish to them a number of different substances, which, though in quantities scarcely perceptible in the water, may accumulate in the plant, which probably perspires only absolutely pure water.

In 1801, I made an experiment on the growth of oats, supplied with a limited quantity of distilled water in a soil composed of pure carbonate of lime. The soil and the water were placed in a vessel of iron, which was included in a large jar, connected with the free atmosphere by a tube, so curved as to prevent the possibility of any dust, or fluid, or solid

tical truths are incontestably established; first, that particular salts enter, so to speak, as natural elements into the composition of certain plants, and that they

matter from entering into the jar. My object was to ascertain whether any siliceous earth would be formed in the process of vegetation; but the oats grew very feebly and began to be yellow before any flowers formed; the entire plants were burnt, and their ashes compared with those from an equal number of grains of oat. Less siliceous earth was given by the plants than by the grains; but their ashes yielded much more carbonate of lime. That there was less siliceous earth, I attribute to the circumstance of the husk of the oat being thrown off in germination; and this is the part which most abounds in silica. Healthy green oats, taken from a growing crop, in a field of which the soil was a fine sand, yielded siliceous earth in a much greater proportion than an equal weight of the corn artificially raised.

The general results of this experiment are very much opposed to the idea of the composition of the earths, by plants, from any of the elements found in the atmosphere, or in water; and there are other facts contradictory to the idea. Jacquin states that the ashes of glasswort, (*salsola soda*), when it grows in inland situations, afford the vegetable alkali; when it grows on the seashore, where compounds which afford the fossil or marine alkali are more abundant, it yields that substance. Du Hamel found that plants which usually grow on the seashore, made small progress when planted in soils containing little common salt. The sunflower, when growing in lands containing no nitre, does not afford that substance; though when watered by a solution of nitre, it yields nitre abundantly.

De Saussure made plants grow in solutions of different salts, and he ascertained that in all cases certain portions of the salts were absorbed by the plant, and found unaltered in their organs.

Even animals do not appear to possess the power of forming the alkaline and earthy substances. Dr. Fordyce found, that when canary birds, at the time they were laying eggs, were deprived of access to carbonate of lime, their eggs had soft shells; and if there is any process for which nature may be conceived most likely to supply resources of this kind, it is that connected with the reproduction of the species.

As the evidence on the subject now stands, it seems fair to conclude, that the different earths and saline substances found in the organs of plants are supplied by the soils in

absorb these salts with avidity wherever they can find them, and never fail to languish in soils where they do not exist; and secondly, that these salts should always be present in manures, the fertilizing properties of which are increased in proportion as they are more abundant; provided, nevertheless, that this proportion must never be in excess, and beyond the actual wants of plants, and that they be not of a nature to stimulate too powerfully in their action.

I will also add that it is a property of plants to prefer the particular salts which are most analogous to their nature. When the *salsola* and *tamarisc* grow side by side, the first will extract from the soil its marine salt, while the latter is equally assiduous in obtaining from it the sulphate of soda. It is owing to this peculiar property of plants, that, even when grown in precisely the same kind of soil, they contain different salts, or, to say the least, in widely dissimilar proportions.

The salts are essential to vegetation; and such is their beneficial effect in quickening the action of the organs of plants, that they may be employed for this purpose, with great advantage, in an unmixed state; and of which mode of employing them I now proceed to speak.

Limestone, by being subjected to the action of fire, is made to part with the carbonic acid which is one of its constituent elements; and in this state it is

which they grow; and in no cases composed by new arrangements of the elements in air or water. What may be our ultimate view of the laws of chymistry, or how far our ideas of elementary principles may be simplified, it is impossible to say. We can only reason from facts. We cannot imitate the powers of composition belonging to vegetable structures; but at least we can understand them; and, as far as our researches have gone, it appears that in vegetation compound forms are uniformly produced from simpler ones; and the elements in the soil, the atmosphere, and the earth, absorbed and made parts of beautiful and diversified structures.—*Davy's El. Ag. Chym.*, pp. 287—291.

a whitish stone, opaque and sonorous, acrid and burning to the taste, absorbing water with noise and heat, and forming in combination with it, a paste which is a pure hydrate.

Limestone of a good quality, may be made to lose as much as even fifty per cent. of its weight by calcination; but it is rarely the case that the heat of ordinary lime-kilns deprives it of more than from thirty-five to forty per cent., when the carbonate is dry.

If, after calcination, limestone be exposed to the air, it absorbs moisture from it with no little avidity, and gradually splits in pieces and divides. At the same time it imbibes from the atmosphere carbonic acid, and is insensibly reduced to an impalpable powder.

In this way lime receives back the principles which it had previously lost by calcination, and is again constituted limestone, or calcareous carbonate, but without its hardness. As the process of recomposition proceeds, lime is gradually deprived of the properties which had been imparted to it by the action of heat; it ceases to be acrid, caustic, and burning; its solubility in water becomes less, and, at length, its affinity for that liquid is almost entirely destroyed.

It is more especially this kind of lime which has been slaked by the air, that is made use of in agriculture. Unslaked lime, by its being too violently stimulating, destroys plants, instead of benefiting them; except, indeed, where it is combined with such manures as will moderate its action, or with substances containing carbonic acid in sufficient quantity to saturate it.

We are indebted to Davy for experiments which throw great light upon the manner in which lime acts upon vegetation. He has shown that the fibrous matter of plants, after being deprived of every portion that is soluble in water, will again furnish soluble substances, when they have been left for some time to macerate in water impregnated with lime.

Thus lime may be employed with great advantage, whenever it is desired to convert the woody and fibrous parts of plants into manures for the improvement of vegetation. But broken limestone, and lime which has reverted completely to a state of carbonate, have not the same effect. It is only lime which has been slaked with water, that should be employed for this purpose ; and to prepare it for use, it must be diluted again with this liquid, and the fibrous materials being then mixed with it, must be left for some considerable time exposed to its action.

It appears then, that lime renders soluble, and converts into nourishment for plants, substances, which, in their natural state, possess not these properties ; its use, therefore, in this respect may be made exceedingly valuable ; and whenever ligneous and fibrous plants are intended to be converted into manure, lime may be employed with great advantage.

If it be proposed to employ for manure animal or vegetable substances that are naturally soluble in water, by mixing them with lime they will be induced to form new compounds, which, though differing entirely from their original character, may, nevertheless, in time become very suitable to be applied to plants. This, however, will require some explanation.

Lime forms with nearly all the soft animal or vegetable substances capable of combining with it, compounds which are not soluble in water ; and it thereby destroys in them, or, at least, greatly diminishes, the power of fermentation. Nevertheless, the character of these compounds becomes gradually changed, by long-continued exposure to the action of air and water ; the lime in this case reverting to a state of carbonate, while the animal and vegetable substances slowly decompose, and afford new products for the wants of vegetation. Lime then, in this instance, is useful in the production of vegetable nutriment in two ways. In the first place, it induces certain substances

which are themselves insoluble in water, to decompose and to form soluble compounds; and secondly, it prolongs the nutritive action of soft animal and vegetable substances, and renders their fertilizing power much more durable than it would be, but for their combination with it.*

* Quicklime, in being applied to land, tends to bring any hard vegetable matter that it contains into a state of more rapid decomposition and solution, so as to render it a proper food for plants. Chalk, and marl, or carbonate of lime, will only improve the texture of the soil, or its relation to absorption; it acts merely as one of its earthy ingredients. Quicklime, when it becomes mild, operates in the same manner as chalk; but in the act of becoming mild, it prepares soluble out of insoluble matter.

It is upon this circumstance that the operation of lime in the preparation for wheat crops depends; and its efficacy in fertilizing peats, and in bringing into a state of cultivation all soils abounding in hard roots, or dry fibres, or inert vegetable matter.

The solution of the question, whether quicklime ought to be applied to a soil, depends upon the quantity of inert vegetable matter that it contains. The solution of the question, whether marl, mild lime, or powdered limestone, ought to be applied, depends upon the quantity of calcareous matter already in the soil. All soils are improved by mild lime, and ultimately by quicklime, which do not effervesce with acids; and sands more than clays.

When a soil, deficient in calcareous matter, contains much *soluble* vegetable manure, the application of quicklime should always be avoided, as it either tends to decompose the soluble matters by uniting to their carbon and oxygen so as to become mild lime, or it combines with the soluble matters, and forms compounds, having less attraction for water than the pure vegetable substance.

The case is the same with respect to most animal manures; but the operation of the lime is different in different cases, and depends upon the nature of the animal matter. Lime forms a kind of insoluble soap with oily matters, and then gradually decomposes them by separating from them oxygen and carbon. It combines likewise with the animal acids; and probably assists their decomposition by abstracting carbonaceous matter from them combined with oxygen; and consequently it must render them less nutritive. It tends to diminish likewise the nutritive powers of albu-

We have presented to us a striking example of the truth of these facts, in the products of certain branches of manufacture. In the process of sugar-refining, for instance, the milk of lime is employed to rid the vegetable sirup of the extractive matter and the albumen which it contains; and which combines with these latter substances, and causes them to rise in the form of a thick insoluble scum, to the surface of the liquid. If this substance be immediately carried to the fields, and there applied to the plants, its effect is to destroy them at once; but if it be deposited in a trench, and suffered to ferment for the space of a year, it forms one of the most powerful manures of which I have any knowledge. The fact here mentioned I have myself abundantly established by twelve years' experience—having, during this time, constantly employed in this manner the frothy substance so abundantly furnished by the juices of the beet, in my establishment for the manufacture of sugar from that vegetable.

From this exposition of the nature and action of lime, we shall be able to derive certain deductions both in relation to its uses and the modes of employing it, which will be found in accordance with the most enlightened experience hitherto obtained in relation to this subject.

It is admitted that lime is principally useful upon broken-up fallow grounds, on meadows, natural as well as artificial, when cleared, and upon miry lands in preparing them for cultivation. In all these cases, there are left in the earth more or less roots, and which being brought in contact with the lime, are men from the same causes; and always destroys to a certain extent the efficacy of animal manures, either by combining with certain of their elements, or by giving to them new arrangements. Lime should never be applied with animal manures, unless they are too rich, or for the purpose of preventing noxious effluvia. It is injurious when mixed with any common dung, and tends to render the extractive matter insoluble.—*Davy's El. Ag. Chym.*, pp. 295, 296.

made almost immediately to serve the purpose of manure, by the solubility which is thus given to the new products which they form. This advantage, however, is not to be obtained, either by spreading the lime at the time of sowing, or at any other time without covering it, or by scattering it over the plants when they are once developed. It should be spread upon the land before the first ploughing, and as fast only as it can be mixed with the soil, in order that it may have no time to lose any part of its fertilizing properties, by being exposed to the action of the air. Subsequent tillage will intermix it more and more intimately with the soil, and bring it closer in contact with the roots; and, at the end of a few months, its action will have been completed.

But in addition to these effects produced by lime, and which I consider exceedingly important, it possesses also other properties, which render it an invaluable agent in agriculture. It is well known that the long continuance of lands in a state of meadow or pasture, and the infertility of turfy and marshy soils give being to innumerable insects, which become, as it were, naturalized to such lands, and that they can be got rid of only after a long time, by means of tillage and the rotation of crops, whereas the application of lime extirpates them at once. It will always be the case, too, that a portion of the weeds will escape every act of tillage, and still remain to foul the soil and injure the crop; when by the use of lime they may be immediately destroyed.

But, that the employment of lime may be attended with these important effects, it is evident, from what precedes, that it must be applied in a caustic state; and for this end it should be prepared in the following manner. Water is to be thrown upon the limestones, and this they will eagerly absorb, giving out, at the same time, heat and smoke, crumbling to pieces, &c. This operation must be prolonged until the stones crumble to pieces in small fragments; after

which the whole mass will gradually be reduced to a dry impalpable powder; and in this state it is to be used.

To prevent any injurious effects to the lungs from this light caustic powder, it may be mixed with moist earth, and made use of in this way. In order that lime may be deprived of none of its properties, it should be buried with the plough, immediately after being spread upon the soil.

The practice of employing lime that has been slaked by the air, and consequently reduced to the state of a sub-carbonate, is becoming more general in France every year, and is productive of valuable results. Doubtless, when prepared in this way, it is less active in its effects; but then, to compensate for this, it requires less precaution, and is attended with no inconvenience whatever in its use.

Lime that has been slaked by exposure to the air, and is reduced to an impalpable powder, is most commonly mixed with manures, and with the best results. It corrects the acidity which prevails in such of these as are produced by the decomposition of certain fruits, as the mash of grapes, &c.; absorbs the juices, which otherwise would either decompose too rapidly, or flow off and be lost; and it fixes the gases, which, but for this, would be dissipated in the atmosphere. This mixture, spread upon the fields, excites vegetation, communicates warmth to soils of a cold nature, renders more friable those which are compact, regulates the fermentation of manures, and furnishes to plants, in suitable proportions, and as their wants require, the nutritive principles with which it is charged. A portion of it will not have been entirely deprived of the property of being soluble in water, and this therefore is introduced in combination with that liquid, into the organs of plants, and there produces those healthful effects, which we ordinarily ascribe to saline substances, when employed in small doses.

Limestone saturated with carbonic acid, though

reduced to a state of powder, has, nevertheless, none of the good effects which belong to quicklime, and that which has been slaked by exposure to the atmosphere. It can, at the best, only be employed to amend the soil, to divide its particles and render it more open, if it be too compact, to facilitate the flow of water, and prepare it the better for tillage, &c.

Limestone not unfrequently contains magnesia, and, whenever this is the case, it modifies in a very singular way, the action of lime. Tennant obtained from limestone, in which the quantity of lime present was no more than from twenty-nine to thirty-one per cent., twenty-two per cent. of magnesia, by pouring upon the mixture of these two earths a solution of nitric acid not quite strong enough completely to saturate it; the liquid continued to be turbid and of a whitish colour.

I have uniformly noticed that water on the surface of earths, whatever may be their nature, if they contain magnesia, is constantly of a whitish colour, and that, on being agitated in the least degree by the wind, it always becomes turbid. These are what are called *white waters*, whenever they form ponds or pools.

Magnesian soils are by no means fertile. Whenever lime containing magnesia is used for agricultural purposes, it no longer produces the same effects; and, to account for this difference in its action, we have but to take into view that the affinity of magnesia for carbonic acid is not as great as that of lime, and that, consequently, whenever these two earths are mixed together, the magnesia retains its caustic character, even after the lime has become saturated with carbonic acid, and is brought back to the state of limestone; so that magnesia may for a long time preserve its caustic qualities, and continue to exercise them injuriously upon plants.*—(See p. 241.)

* There are cases in which magnesian limestone is used with good effect.

Among some specimens of limestone which Lord Somer-

ON THE USE OF LIME AS A MANURE.

[BY M. PUVIS.]

Translated from the French by E. Ruffin, Esq.

INTRODUCTORY REMARKS BY JAMES RENWICK, LL.D.

THE task of adapting an Introduction explanatory of the chymical principles most important in agriculture to the Essay of Mr. Puvis, was undertaken at the

ville put into my hands, two marked as peculiarly good proved to be magnesian limestones. And lime made from the Breedon limestone is used in Leicestershire, where it is called hot lime; and I have been informed by farmers in the neighbourhood of the quarry, that they employ it advantageously in small quantities, seldom more than twenty-five or thirty bushels to the acre. And that they find it may be used with good effect in larger quantities upon rich land.

A minute chymical consideration of this question will lead to its solution.

Magnesia has a much weaker attraction for carbonic acid than lime, and will remain in the state of caustic or calcined magnesia for many months, though exposed to the air. And as long as any caustic lime remains, the magnesia cannot be combined with carbonic acid, for lime instantly attracts carbonic acid from magnesia.

When a magnesian limestone is burnt, the magnesia is deprived of carbonic acid much sooner than the lime; and if there is not much vegetable or animal matter in the soil to supply by its decomposition carbonic acid, the magnesia will remain for a long while in the caustic state; and in this state acts as a poison to certain vegetables. And that more magnesian lime may be used upon rich soils, seems to be owing to the circumstance, that the decomposition of the manure in them supplies carbonic acid. And magnesia in its mild state, that is, fully combined with carbonic acid, seems to be always a useful constituent of soils. I have thrown carbonate of magnesia (procured by boiling the solution of magnesia in super-carbonate of potassa) upon grass, and upon growing wheat and barley, so as to render the surface white; but the vegetation was not injured in the slightest degree. And one of the most fertile parts of Cornwall, the Lizard, is a district in which the soil contains mild magnesian earth.

instance of a valued friend, James Wadsworth, Esq., of Geneseo. The translation which is employed was liberally placed at my disposal by the very intelligent and practically skilful editor of the *Farmer's Register*. He has the merit of first bringing the Essay of Mr. Puvis before the American public, and, taken in connexion with his own Essay on Calcareous Manures, he has thus made us acquainted not only with all that was previously known in the theory or practice of the use of Lime in agriculture, but has added himself some most valuable theoretic views, which he has

The Lizard Downs bear a short and green grass, which feeds sheep, producing excellent mutton; and the cultivated parts are among the best lands in the country.

That the theory which I have ventured to give of the operation of magnesian lime is not unfounded, is shown by an experiment which I made expressly for the purpose of determining the true nature of the operation of this substance. I took four portions of the same soil: with one I mixed one twentieth of its weight with caustic magnesia, with another I mixed the same quantity of magnesia and a proportion of a fat decomposing peat equal to one fourth of the weight of the soil. One portion of soil remained in its natural state: and another was mixed with peat without magnesia. The mixtures were made in December, 1806; and in April, 1807, barley was sown in all of them. It grew very well in the pure soil; but better in the soil containing the magnesia and peat, and nearly as well in the soil containing peat alone: but in the soil containing the magnesia alone, it rose very feeble, and looked yellow and sickly.

I repeated this experiment in the summer of 1810 with similar results; and I found that the magnesia in the soil mixed with peat became strongly effervescent, while the portion in the unmixed soil gave carbonic acid in much smaller quantities. In the one case the magnesia had assisted in the formation of a manure, and had become mild; in the other case it had acted as a poison.

It is obvious, from what has been said, that lime from magnesian limestone may be applied in large quantities to peats; and that where lands have been injured by the application of too large a quantity of magnesian lime, peat will be a proper and efficient remedy.—*Davy's El. Ag. Chym.*, pp. 288—301.

also established by successful and judicious experiments on his own farm.

The chymical facts and principles which are applicable to agriculture are neither numerous nor complex. They are, however, to be found only in works on general chymistry, in which they are intimately associated with laws and phenomena of a more abstruse description, and in connexion with which they constitute a science of which the most learned are still students, and to attain which in its existing form may require years of close and attentive study. The language, too, of chymistry, which, to those who study it in a regular course, serves as an artificial memory, and single words of which call up long trains of thought and experiment, presents to the uninitiated all the difficulties of a foreign tongue.

Yet it cannot be doubted, that the practical farmer may derive important benefit from acquiring so much of this language as will enable him to understand the chymical explanation of the numerous changes which are continually taking place in the natural actions which it is his high privilege to call into his service, to direct in part, and modify in degree. So also are there certain chymical elements and compounds, with the properties of which he ought to be acquainted if he wish to be able to direct his practical skill with more effect, even in circumstances familiar to him, but which may be absolutely necessary, or will at any rate save waste of labour and loss of time, when the knowledge acquired by practice in one place is to be employed in a new situation, and under a change of circumstances.

It is the object of this introduction to exhibit, in such form as may be intelligible to those who have not made general chymistry an object of study, a concise view of such of the laws and facts of that science, as are absolutely necessary for the agriculturist who may wish to improve his practice, and which are more particularly required by those who wish to avail them-

selves of the knowledge contained in the subjoined essay. To do this has been found no easy task. It would be in itself difficult, but to the author of this introduction has been more particularly so, as he has for years been in the habit of imparting instruction to those whose habits of life and thoughts are as remote as possible from those of the practical farmer; persons to whom the peculiar language of chymistry is an aid instead of an impediment; and who, with ample time at their command, have an opportunity of pursuing the study of the science step by step. Fully aware of these difficulties, both general and peculiar, this attempt would not have been made, and certainly not persisted in, had it not been for the instances of an intelligent, scientific, and successful farmer, who has urged the completion of the task as an object likely to be beneficial to those, who, with perhaps equal zeal and native powers of mind, have not enjoyed, like himself, the advantages of a scientific education.

The atmosphere which surrounds our earth is the first object to which our attention should be directed. This is the vehicle of the moisture, which, whether it fall in the form of rain or dew, run in streams or issue from springs, is absolutely essential to the success of the farmer's labour. It is also, as we shall presently see, important to him on other accounts.

The greater part of the atmosphere is made up of a mixture of substances, each of which has the same mechanical properties as the whole mass. These air-like substances are known to chymists by the name of *gases*.

Of these gases, two make up by far the greater portion of atmospheric air, and exist in it in the proportion of about four to one. That which is the largest in quantity and makes up nearly four fifths of the whole atmosphere, is called, in the Essay of M. Puvlis, by the name of azote, but is more usually known in English by the name of nitrogen.

This substance, although in the largest proportion,

is the least important of the gases in its chymical effects. It does not aid in supporting the life of animals, nor in maintaining the burning (*combustion*) of inflammable bodies.

The part of the atmosphere which is absolutely necessary for these purposes, is called by the name of *oxygen*, and nearly makes up the remaining fifth part of atmospheric air. In its support of life it always, and in maintaining combustion often, unites with a chymical element, which is called *carbon*. This is familiarly known as forming the principal part of charcoal. In its union with carbon, oxygen forms a peculiar gas known by the name of carbonic acid.

Carbonic acid is always found in small quantities in the atmosphere to which it is furnished by the breath of animals and the fumes of burning bodies. It is, when in considerable quantities, fatal to the life of animals, but is prevented from accumulating to an injurious extent in consequence of its being taken up by water; it is therefore dissolved, in proportions about equal to those in which it is formed, by rivers, lakes, the ocean, and the moisture of the soil.

Water exists in the atmosphere in the form of vapour. The great source of this vapour is the extended surface of the ocean; and it is governed by a mechanical law, by which it is continually tending to distribute itself uniformly over the whole surface of the earth. It may thus exist in as large quantities over the surface of the driest land as over that of the ocean itself. This tendency to equal distribution is continually counteracted by the changes in the sensible heat (*temperature*) of the atmosphere, and of the surface of the earth, which follow the alternations of day and night, and the vicissitudes of the seasons. By these alternations and changes, the vapour is caused to fall (*precipitated*) in the form of rain, snow, hail, dew or white frost, according to circumstances. As such changes of temperature are more frequent on the land than on the

ocean, the water which falls on the former in either of these forms is greater in quantity than that which falls on equal surfaces of the latter. Thus, by a wise and benevolent provision of Providence, the water of the ocean is continually furnishing vapour, which is precipitated on the land for the support of vegetation and the supply of springs, and whose excess is poured back into the ocean in streams and rivers.

Water has been found by chymists to be a compound substance, made up of two elements. One of these, which forms eight ninths of its weight, is the gas already mentioned under the name of oxygen; the other, a peculiar gas, known by the name of *hydrogen*.

Hydrogen, when free, is the lightest of all known bodies rising and floating in atmospheric air; it not only combines with oxygen, to form water, but with carbon to form a great variety of compounds—gaseous, liquid, viscid, and solid. It also combines with nitrogen, and forms a gas known by the name of ammonia, which is well known by the peculiar smell it gives to spirits of hartshorn (*liquid ammonia*).

Hydrogen also combines with sulphur, forming a gas known by the name of sulphuretted hydrogen; this exists in the atmosphere, but in such small quantities as only to be detected by the nicest chymical tests. It combines in like manner with phosphorus, forming phosphuretted hydrogen gas, whose presence in the air is occasionally perceptible.

Oxygen, as we have seen, unites with carbon, to form a gas which we have called carbonic acid.

This receives the latter part of its name from its similarity in properties to an extensive class of compound bodies, known by the name of *the acids*. The greater part of these, like carbonic acid, are combinations of inflammable bodies with oxygen. The most important of these in reference to our present object, are the sulphuric and phosphoric acids; named from the two substances (sulphur and phosphorus) which

are their bases. Muriatic acid may also be mentioned here, although its composition is of a different character. Oxygen unites with other bodies to form a class of compounds known under the name of oxydes.

The acids unite with earths, alkalies, and metallic oxydes, to form a class of compounds known under the general name of salts. These are named from the two substances which enter into their composition: thus, the salt formed of sulphuric acid and the earth lime is called sulphate of lime. The substances which unite with acids to form salts, are called the *bases* of the respective salts.

Of these bases, the alkalies and earths are the most important. Of the alkalies, it is only necessary to know the names of two, namely, *potassa* and *soda*, and to be aware that their distinctive properties, are: to possess an acrid taste, a caustic operation, to render oils capable of mixing with water, and to neutralize the properties of acids.

The earth which chymists call by the name of *silex* or *silica*, is found almost pure in flint and rock crystal; it is also almost pure in sharp colourless sands, and is by far the larger part of sands of every description. So far as the farmer need know its properties: it is hard, rough to the touch, has no attraction for water, which it permits to filter through, or evaporate from it, with the greatest ease. It is capable of uniting with the other earths in compounds which are called silicates, and is the only earth which enters into the formation of soils uncombined with the others or with other elements.

The earth which chymists call by the name of *alumina*, is so named because it is obtained by them in a pure form from the well-known salt called alum, of which it is the basis. Its most marked characteristic is plasticity: that is to say, it may be formed into a paste with water, will then easily receive any form which may be given it, and retain that form unaltered, even by violent heat. It never exists in soils unmixed,

but in intimate association, or more probably chymical combination with silica, it is the well-known substance called clay, or argillaceous earth. White clays are this combination nearly pure, and coloured clays often contain it with no other addition than metallic colouring matter. Clay retains the plastic property of alumina; it therefore causes soils to be retentive of moisture; and, when they dry, makes them form tough clods or crusts, similar in character to sun-dried brick.

Soils which contain clay are often also mixed with sand, or with an excess of silica in grains, which does not enter into the composition of the clay. Such a soil is less liable to form a tough crust than a pure clay, but it will require a very large proportion of sand to destroy this property altogether.

Clay mixed with sandy soils renders them more retentive of moisture. Sand and clay have therefore been used as manures for each other; but it may reasonably be doubted whether all the advantage that has been anticipated by some from this process, can be realized, as such a mixture will be merely mechanical.

Loamy soils are generally said to be mixtures of sand and clay; they undoubtedly usually contain both these earths and even sometimes a large excess of sand. But we shall give reasons for believing that loams owe their peculiar value to a combination of clay with another substance, by which a change is produced in its chymical characters.

Lime is familiarly known to farmers by the same name that is generally used by chymists. It is obtained by the aid of heat from rocks which go by the name of limestones. These are combinations of lime with carbonic acid, which is fixed in them by chymical attraction, but which, when driven off by heat, takes the same form as the air of the atmosphere, or becomes a gas. This gas from this circumstance has been called *fixed air*, by which name it is

often known when causing the sparkling and froth of cider and beer. The principal part of limestone is therefore called by chymists *carbonate of lime*. Carbonate of lime is also found in shells, both those of living animals and those which exist in the ground in a fossil state. In this former it is mixed with animal matter, which is more or less separated from the latter according to the time which has elapsed since the death of the shell-fish.

Marl, in the sense in which the term is used by chymists, is a mixture of clay with carbonate of lime. The English writers on agriculture have not observed this distinction, and the term is sometimes applied by them to a decomposed chalk, which may contain little or no clay; and sometimes to clay which contains no carbonate of lime. In fact, the name is frequently applied by them to any earthy matter found below the vegetable soil, which is capable of increasing its fertility. From this misapprehension, the substances which go by the name of marl in New Jersey, Maryland, and Virginia do not correspond with the chymical definition, but are generally beds of fossil shells mixed in various proportions with earthy and saline matters of various kinds.

Lime is a substance very different in its characters from the two earths of which we have previously spoken. When prepared by heat from any of the original forms of its carbonate, it retains their shape unaltered, but may have its colour changed, and always loses considerably in weight. It is now acrid, caustic, and corrosive, and has some properties in common with potash, which are therefore alkaline. Of these the most important is, that it unites with acids to form compounds included in the general class of salts. Of the salts of lime which are important to the farmer, the three principal are: the *carbonate*, which, as we have stated, is found in limestone, chalk, shells, and marl; the *sulphate*, in which lime is combined with sulphuric acid, and which in combina-

tion with water is the substance so well known to our farmers under the name of plaster of Paris, or less familiarly by that of gypsum; the *phosphate*, which constitutes a large part of the bones of animals.

Lime, when exposed to the air, attracts carbonic acid, which is always to be found in the atmosphere; it thus passes back to the state of carbonate, but in so doing gradually falls to powder, and is then said to be *air-slaked*. If slaked with water, it also falls to a powder, which still retains the caustic character of the burnt lime; but this powder, when exposed to the air, unites with carbonic acid more rapidly than when in mass.

Lime, in its caustic state, has the property of rapidly decomposing vegetable and animal substances, thus hastening the natural processes by which they are finally destroyed; or, to speak more properly, have their elements resolved into new combinations. The offensive and unwholesome gases, which are given out by this composition, are absorbed by the lime, and prevented from mixing with the air. The same property is possessed in a less degree by the carbonate of lime, and probably by its other compounds; but in order that either this earth or its compounds shall manifest this property, they must be in small fragments, or, which is better, in fine powder.

Wet sand and plastic clay, and those soils to which they give their characters, also possess the property of absorbing gases; but they have this in a very inferior degree to lime and its compounds. As the gases generated by the decomposition of vegetable and animal substances form a large part of the necessary food of plants, it is obvious that a soil which contains the carbonate of lime, may retain and store them up for use, while they will be lost in soils of a different character.

Carbonate of lime may also be made a most important article in the preservation of the most valuable parts of putrescent manures, until they can be

applied to the soil. In this way marl is applied to a great extent in China; the night soil of their numerous population is there formed into cakes like bricks, with marl, and thus loses its offensive smell; but when these are applied as manure to the land, they give out the gases again as they are required for the nourishment of plants. So also in Norfolk, the site for dunghills is prepared by a layer of marl, which is incorporated with the manure from time to time, and retains the gases which would otherwise be lost.

Lime may therefore be applied in its caustic form in some cases in agriculture, for it will hasten the decomposition of animal and vegetable matters which might otherwise be inert; it will also neutralize acids, which experienced farmers well know to exist in many soils, which they in consequence call sour. But the latter purpose will be answered as well by the carbonate of lime, which may be applied as it exists in marl or shells, or as it may be prepared by grinding limestone. Caustic lime is also dangerous in its application, for it will corrode and destroy living vegetables, and hasten the decomposition of the vegetable matter of the soil to such a degree as to injure its fertility. Except upon turf-bogs, and land loaded with timber not wholly decomposed, quick or caustic lime ought not to be used; but to burn lime, and then by slaking to reduce it to the form of fine powder, which is speedily carbonated by exposure to the air, is a more ready, and generally a cheaper mode of obtaining the carbonate in a convenient form, than to grind limestone to powder in mills. Yet for many of the most valuable uses of lime in agriculture, the latter method, if as cheap, would answer as well.

Lime slowly combines with the earth silica, and produces a compound very different in character from either. It is this, to cite a fact in proof of our statement, which gives the hardness and solidity to ancient mortar. The carbonate of lime will serve to form this compound; and thus, when it has had time

to act upon sand, it renders a silicious soil more retentive of moisture; while, if applied to clay, by combining with its silicious matter, it renders it more friable; and it is to the formation of this compound by slow degrees, that we are inclined to ascribe the valuable mechanical properties of loamy soils, and the gradual amelioration produced by the use of lime, marl, and shells as a manure.

Besides silica, alumina, and lime, an earth called magnesia is likewise found in some soils. It is also, in the form of carbonate, a frequent constituent of limestones. This earth has many properties in common with lime; like lime it is capable of neutralizing acids; and when deprived of carbonic acid by heat, corrodes vegetable substances. It probably also hastens putrefaction, and both it and its carbonate are capable of absorbing the gases let loose in that natural process. It is, however, of little interest in agriculture, except as a part of some of the limestones which are used as manure. These, if applied in large quantities, are sometimes very injurious to vegetation; the reason of this is, that magnesia does not repass to the state of carbonate as rapidly as lime, and therefore retains its corrosive quality long after the lime has again become mild by its union with carbonic acid. In less quantities, however, the magnesian limestones may serve as a manure, but their application requires great caution, particularly when the quantity of magnesia amounts to twenty-five per cent.

All of the simple substances we have mentioned, except perhaps the last, either separate or in various states of combination, exist in plants. The manner and character of the combination are influenced by the vital action of the plant, which causes them to form compounds, often in direct opposition to the manner in which the ordinary laws of chymistry would direct. It thus happens that so soon as the plant ceases to live, these chymical laws, being no longer impeded,

begin to exert their influence; and if it be in such a state as will admit of the several elements acting readily upon each other, a decomposition, more or less rapid, of the vegetable structure ensues. It is a law of chymistry, that its action is always aided by the bodies being in a fluid state, and the action is often impossible when the bodies are perfectly free from moisture. Hence the direct chymical action, and consequent decomposition, take place with greater certainty and more rapidity in green juicy and succulent vegetables, than upon those which have been deprived of moisture either naturally or artificially. Thus grass, if heaped up in a recent state, decomposes, and if but partially dried, is heated, and may even take fire, by the chymical action of its elements; while, if dried by exposure to the sun and air, and then laid up in a dry place in the form of hay, it is almost indestructible. A moderate degree of heat and access to air are also necessary to promote the chymical action by which decomposition is effected. This decomposition is often attended with motion among the parts; and always, if the mass has a liquid form, as in the expressed juice of vegetables, or in the steeps employed by distillers and brewers; it goes in general terms by the name of fermentation. When the vegetable matter abounds in starch, the first change is the conversion of this principle into sugar. Sugar, if thus formed, is next converted into alcohol, that is, if it previously existed in the plant. The presence of alcohol gives the liquid in which it exists the character of vinous liquors, and if these are permitted to remain in a turbid state, a farther fermentation converts them into vinegar; and finally vinegar is farther decomposed, and the vegetable matter giving out an offensive smell, is said to putrefy. If the substance be not an expressed juice or liquid steep, these several stages of fermentation ensue with rapidity, may be going on at the same time, and are sometimes so speedy in their course

that no other action but the putrefactive fermentation can be detected. Animal bodies are subject to the same laws, and go through the same stages of fermentation, but the rapidity with which they run into putrefaction is even greater; still there are some cases, as in that of milk, where the vinous stage can be occasionally, and the acetic, distinctly observed. Thus, a vinous liquor is prepared in some countries from milk, and the sour taste which appears in it when kept, arises from the presence of vinegar.

In the several stages of fermentation, parts of the vegetable assume the form of gas or vapour, and are given out to the air. The gases which have been detected, are carbonic acid, a gaseous compound of carbon and hydrogen, and in some instances ammonia. The vapour is that of water, which escapes in greater quantities than it would under ordinary circumstances, in consequence of the heat with which the process is attended. If exposed to rain, soluble salts, with earthy and alkaline bases, are washed from the mass. Finally, a mass of earthy consistence alone remains, which on examination is found to be made up of earths, insoluble salts, and carbon, being, in fact, identical with vegetable mould.

We may hence infer that the following elements exist in vegetable bodies:—

1. Oxygen, developed in the carbonic acid and water.
2. Hydrogen is in the water and carburets of hydrogen.
3. Carbon.
4. Earths.
5. Alkalies.
6. Nitrogen, occasionally developed in the form of ammonia.
7. Acids, remaining in the insoluble, or washed away in the soluble salts.

The chymical examination of vegetable bodies ought of course to lead to similar results. This examination has been conducted in three different ways.

1. With the view of discovering the nature of the compounds, called vegetable principles, which exist ready formed in plants.
2. For the purpose of discovering the chymical elements contained in these principles.
3. By the destructive action of heat, under which some of the elements are wholly separated, and others enter into new combinations.

In the first of these methods there have been detected:—

- I. Certain peculiar acids, of which we may cite:—
 - (1.) Acetic acid, which, mixed with water, forms common vinegar;
 - (2.) Citric acid, which is found in the lemon and orange;
 - (3.) Malic acid, which exists in the apple;
 - (4.) Tartaric acid, in the juice of the grape;
 - (5.) Oxalic acid, in the wild sorrel.
- II. Certain substances of alkaline character, found principally in medicinal plants, to which they give their peculiar virtues.
- III. Gum, resin, oils, sugar, starch, and two substances approaching to animal matter in their characters, namely, albumen and gluten; the former of these has a resemblance to the white of eggs, the latter to animal gelly or glue.

Many other principles are separated by the same method in different plants, but need not be enumerated by us.

The basis of this method consists in acting upon vegetables by water, ether, or rectified spirits, (alcohol,) and the principles above enumerated are either simply, or in the state of combination in which they exist in plants, soluble in at least one of the liquids we have named.

In all cases some insoluble matter is left, and this is known by the name of the woody fibre.

When these principles are treated by the second method, oxygen, hydrogen, and carbon, are the uniform

results, but in different proportions in the different cases; nitrogen is also detected in some of them, as, for instance, in the alkaline principles and in gluten. This method does not appear to be adequate to determine whether earths and alkalies are, or are not, parts of these vegetable principles. From the very remarkable fact, that some of those substances, which are very dissimilar to each other, yield exactly the same proportions of oxygen, hydrogen, and carbon, we may fairly conclude by chymical analogy, that one or the other, or perhaps both, contain some substances which have escaped the analysis. As an instance we may cite starch and sugar, whose characters are so dissimilar that no danger can exist of mistaking the one for the other; and yet their analysis by the second method gives identical results.

The third method may be understood by comparing it with the process used in making charcoal. If this be so far altered that the heat employed shall not arise from the combustion of a part of the substance to be examined, but from one merely used as fuel, and if the matters which escape in smoke are condensed and collected, we shall have that employed occasionally on a large scale by operative chymists. In this way charcoal will be, as usual, obtained in the solid form. The condensable products will be water, tar, turpentine, or resin; and the acid which gives that character to vinegar, but which in the present case, in union with the tar and water, is called pyroligneous acid.

If the charcoal be burnt in a current of air, all its carbon is converted, by union with the oxygen of the atmosphere, into carbonic acid, leaving a residue familiarly known as ashes. The ashes are made up partly of soluble and partly of insoluble matter. The soluble matter is separated by the familiar process of making lie, and the lie, if evaporated, leaves the solid substance so well known as potash.

Potash is principally composed of a carbonate of potassa, but contains, besides, silica, rendered soluble

by the alkali, sulphate and muriate of potassa, and a peculiar acid known by the name of ulmic, which is a compound of carbon, hydrogen, and oxygen. The insoluble part is made up of carbonate of lime, sulphate and sometimes phosphate of lime, silica. The carbonate of lime has probably in no case existed in the living plant, but arises from the destruction by heat of the peculiar acid of the plant; as, for instance, the citric, the oxalic, or the tartaric; all of which are by fire converted into carbonic acid.

The quantity of ashes is extremely various, as is their proportion of the several soluble and insoluble substances, we have mentioned. Thus the ashes of the stalk of Indian corn yields twelve and a half per cent. of ashes, while the soft woods do not furnish more than two parts in a thousand. The proportion of the sulphate and phosphate of lime is even more various. Thus, in some cases the presence of the sulphate is hardly perceptible, while of the ashes of clover it forms a large proportion of the whole weight. Phosphate of lime is found in the proportion of fifteen per cent. in the grain of wheat.

Water is not only one of the principal component parts of all plants, but is also the sole vehicle of their nutriment. At each extremity of the small fibres into which the roots of plants are divided, is an opening through which that fluid enters; and it appears that, except in the case of a plant having lost its vigour by continued drought, it is only through this channel that water can enter. By a powerful action inherent in living vegetables, water, which with all the matters it is capable of holding in solution, becomes the sap,* is raised to the highest parts of the plants, and forced to their most distant extremities. It has been ascertained that plants do not possess the power of rejecting even those substances which are most noxious to them; it is therefore probable that the character of

* See Roget's Bridgewater Treatise.

the fluid admitted is the same in all the plants which grow upon the same soil. Whether it undergoes any change in the root does not appear certain, but it has recently been maintained that every description of plant throws off by the surface of its roots such matter as, if retained, would be injurious; but this opinion does not appear to be established.

The sap, when carried up to the leaves, undergoes an important change, principally owing to the action of solar light. When exposed to light, the leaves of plants give out oxygen in considerable quantities. This proceeds from the decomposition of the water and carbonic acid, the remaining elements of which two substances and a portion of their oxygen enter into new combinations. These combinations have different characters in different vegetables, but are most familiarly known in the shape of gum and resin. These still contain the earthy and saline matter carried up by the sap, and after they are formed return downward toward the roots. In their descent they deposite the several parts which minister to the growth of the plant—the leaves, the bark, and the woody fibre. They also appear to be forced with powerful energy into the flower and the growing fruit, and in these a still more important action is carried forward, by which the reproduction of the species is ensured.

The matters which the water that enters by the root may hold in solution, are either derived from the atmosphere or from the soil. In its passage through the air it will carry with it a considerable proportion of carbonic acid, and all the sulphuretted hydrogen it meets with. It will also take up a small quantity of oxygen, and of carburetted hydrogen, and a still less quantity of nitrogen. From the soil it will take all the more soluble salts, small quantities of sulphate, phosphate, and carbonate of lime, provided they be present, and silica. So also if the soil contain animal matter, or vegetables of which nitrogen forms a part, the ammonia generated by their decomposition will

likewise be dissolved by the water. In like manner the carbonic acid, which has arisen from the decomposition of vegetable or animal matter, and has not yet escaped, and the soluble compounds of carbon, oxygen, and hydrogen, which are generated by the same process, will have been taken up, and carried by the water into the root of the plant. It will thus appear that, contrary to the opinion of Mr. Puvis, the atmosphere furnishes but little of the fixed elements of plants, with the exception of sulphur and carbon; and that even if the growth of plants were to depend wholly upon the carbon obtained in the form of carbonic acid from the atmosphere, their growth must be slow and feeble. It will also appear, that if lime do not exist in the soil, but few plants can find nourishment; and that for the ripening of the seeds of grain phosphorus must be furnished also. The latter substance may be absorbed in small quantities from the phosphuretted hydrogen, which is occasionally present in the atmosphere; but a more certain supply ought to be sought in putrescent manure, and particularly in that of animal origin.

The uses of lime in agriculture, as will appear from the foregoing remarks and the reasoning of the essay, are as follows:—

1. When a soil contains inert animal or vegetable matter, their decomposition may be promoted, and it may be rendered fit for the food of plants, by the addition of caustic lime.

2. If the soil contain acids, they may be neutralized either by caustic or carbonated lime, and besides, the organic matter whose decomposition may have been prevented by the acid, will be permitted to putrefy.

3. Soils containing too much silica, or in other words those which are sandy, are made more retentive of moisture by the addition of lime or its carbonate.

4. Clays may be rendered less retentive of moisture, and more friable by the same means.

5. The gases which escape when vegetable or ani-

mal matter putrefy, are retained in the soil by means of lime or its carbonate; and thus a given quantity of manure, or the original vegetable matter of the soil, will retain its efficacy longer. By a recent discovery, it has also been ascertained that the decomposition of plants yields a peculiar acid, called the humic, which forms with lime a salt sparingly soluble in water. The generation of this salt also serves to render the nutriment contained in the soil more lasting.

6. Lime and its compounds are absolutely necessary, as constituent parts, to the growth of many plants. The sulphate is essential to the growth of clover, and the phosphate to that of wheat. Hence the efficacy of plaster of Paris and crushed bones as manures.

7. If lime or its sulphate be employed as the means of raising green crops, which have but small exhausting powers, the fertility of a soil may be maintained by ploughing them in, or increased by using them to feed cattle whose manure is applied to the ground.

J. R.

On the different modes of improving the soil.—To improve the soil is to modify its composition in such manner as to render it more fertile.

This definition, which might be extended to manures charged with vegetable mould [*humus*] or animal substances, which also modify the composition of the soil, is limited by French agriculture to substances which act upon the soil, or upon plants, without containing any notable proportion of animal or vegetable matter.

It is said that manures, [putrescent or enriching,] serve for the nutriment of plants. But it is the same as to substances improving to the soil, which furnish to it matters which it needs to be fruitful, and which furnish to vegetables, the earth and saline compounds which enter as essential elements in their composition, their texture, and their products. Such

improving substances may well be regarded as nutritive.*

Thus lime, marl, and all the calcareous compounds employed in agriculture, since they furnish lime and its compounds, which sometimes form half of the fixed principles of vegetables, ought also to be considered as aliments; or, what comes to the same, as furnishing a part of the substance of vegetables. Thus again, wood-ashes, pounded bones, burnt bones, which furnish to vegetation the calcareous and saline phosphates which compose a sixth of the fixed principles of the stalks, and three fourths of their seeds, ought well to be considered, and surely are, nutritive.

What, then, particularly marks the distinction between manures which improve the soil [*amendemens*] and elementary manures, [*engrais*] is, that the former furnish, for the greater part, the fixed principles of vegetables, the earths, and salts, which are abundantly diffused throughout the atmosphere, whence vegetables draw them, by means of suitable organs; and what is most remarkable, is, that the vegetable, by receiving the fixed principles of which it has need, acquires, as we shall see, a greater energy to gather

* The two classes of manures which are described generally above, are conveniently designated in French each by a single word. "*Engrais*," which we can only translate as manure, is limited in signification to such substances as directly enrich soils and feed growing plants—and "*amendemens*," signifying substances which alter and improve the constitution, texture, and indirectly, the fertility of soil, but the operation of which is not to furnish food to plants. In speaking of the *action* of these different classes, the sense may be rendered, though not very precisely, by the words "enrich" and "improve;" but there is no one English term that will convey the meaning of either class of substances. "Alimentary manures" will be used for the first class, and "manures improving the constitution of soil," or some similar awkward, but descriptive phrase, can only render the meaning of the word "*amendemens*," unless "improvers" could be tolerated as a substitute for convenience.—**TR.**

for its sustenance the volatile principles which the atmosphere contains.

The greater part, then, of soils, to be carried to the highest rate of productiveness, require manures to improve their constitution. Alimentary manures give much vigor to the leafy products—but they multiply weeds, both by favouring their growth and conveying their seeds; and they often cause crops of small grain to be lodged, when they are heavy. Manures which improve the soil, more particularly aid the formation of the seeds, give more solidity to the stalks, and prevent the falling of the plants. But it is in the simultaneous employment of these two means of fertilization by which we give to the soil all the active power of which it is susceptible. They are necessary to each other, doubling their action reciprocally; and whenever they are employed together, fertility goes on without ceasing; increasing instead of diminishing.

The greater part of improving substances are calcareous compounds. Their effect is decided upon all soils which do not contain lime, and we shall see that three fourths, perhaps, of the lands of France are in that state. Soils not calcareous, whatever may be their culture, and whatever may be the quantity of manure lavished on them, are not suitable for all products; are often cold and moist, and are covered with weeds. Calcareous manures, by giving the lime which is wanting in such soils, complete their advantages, render the tillage more easy, destroy weeds, and fit the soil for all products.

Improving substances have been called *stimulants*; they have been thus designated, because it was believed that their effect consisted only in stimulating the soil and the plants. This designation is faulty, because it would place these substances in a false point of view. It would make it seem that they brought nothing to the soil nor to plants; and yet their principal effect is to give both principles which

are wanting. Thus the main effect of calcareous manures proceeds from their giving, on the one hand, to the soil the calcareous principle which it does not contain, and which is necessary to develop its full action on the atmosphere; and, on the other hand, to vegetables, the quantity which they require of this principle for their frame-work and their intimate constitution. It would then be a better definition than that above, to say, that to *improve* the soil is to give to it the principles which it requires, and does not contain.

Importance of manures which improve the constitution of soils.—The question of improving manure is of great interest to agriculture. This means of meliorating the soil is too little known, and above all, too little practised in a great part of France; and yet it is a condition absolutely necessary to the agricultural prosperity of a country. In the neighbourhood of great cities, alimentary manures being furnished on good terms may well vivify the soil; but animal manures can suffice only in a few situations, and those of small extent; and in every country where tillage is highly prosperous, improving manures are in use. The department of the north in France, Belgium, and England, owe to them, in a great measure, their prosperity. The department of the north, which is, of all Europe, the country where agriculture is best practised and the most productive, spends every year, upon two thirds of its soil, a million of francs in lime, marl, ashes of peat and of bituminous coal [*houille*],* and it is principally to these agents, and not to the quality of the soil, that the superiority of its production is owing. The best of its soil makes part of the same basin, is of the same formation and same quality, as a great part of Artois and Picardy, of which the products are scarcely equal to half the rate of the north. Neither is it the quantity of mead-

* Statistique du department du Nord.

ow-land which causes its superiority; *that* makes but the fifth part of its extent, and Lille, the best *Arrondissement*, has scarcely a twentieth of its surface in meadow, while Avesne, the worst of all, has one third. Nor can any great additional value be attributed to artificial meadows, since they are not met with except in the twenty-sixth part of the whole space. Neither can this honour be due to the suppression of naked fallows, since, in this country of pattern husbandry, they yet take up one sixth of the ploughed land every year. Finally, the Flemings have but one head of large cattle for every two hectares* of land, a proportion exceeded in a great part of France. Their great products then are due to their excellent economy and use of manures, to the assiduous labour of the farmers, to courses of crops well arranged, but, above all, we think, to the improvers of soil, which they join to their alimentary manures. Two thirds of their land receive these regularly; and it is to the reciprocal action of these agents of melioration, that appears to be due the uninterrupted succession of fecundity which astonishes all those who are not accustomed continually to see the products of this region.

At this moment, upon all points in France, agriculture, after the example of the other arts of industry, is bringing forth improvements; in all parts especially, cultivators are trying, or wishing to try, lime, marl, ashes, and animal charcoal. It is this particular point in progress, above all, for which light is wanting; and this opinion has induced the preparation of this publication. For more than thirty years the author has devoted himself, from inclination, to agriculture; but he has been especially attentive to calcareous manures. He has studied in the practice of much extent of country, in that of his own particularly, in personal experiments, and in what has been

* The hectare is very nearly equal to two and a half English or American acres.—Tr.

written on them, both by foreigners and countrymen. An *Essay on Marl* has been the first fruit of his labours; an *Essay on the Use of Lime* will soon be ready: it is with these materials that he now sets himself to work. To prepare for this object, a series of articles, of the nature of a recapitulation rather than of a regular work, it was necessary to be concise, and yet not to omit anything essential. It is proper, then, that he should limit himself to the prominent parts of his subject, those especially useful to practice. His advice will then be as often empirical as regular, and his directions will be precise, although supported by a few developments.

An extract from this work has appeared in the *Encyclopedie Agricole*: here it will again appear, but in the form of separate articles, which will be corrected by a general systematic view of the theory, founded on practice. This is the moment for multiplying publications on this subject, because in almost all parts of France it is the point in agriculture most controverted; that which induces the most labour and the greatest expenditure; which presents most doubts; and which has consequently most need of being made clear.

We shall not here enlarge upon the manner in which improving manures act: we will put off this important question, with its developments, to the article on lime. Here we only present the theory. Hereafter, that which we will hazard will be founded upon facts, and yet we do not promise these developments, except so far as may be necessary for the purpose of enlightening and directing practice.

Of the various kinds of Improving Manures.—The first in order, and the most important, are calcareous manures. We comprehend under this name, lime, marl, old plastering mortar, and other rubbish of demolished buildings, beds of fossil shells [*fahlun*],* or

* "*Fahlun*. Beds formed by shells. There is one of these immense beds in Touraine. The cultivators of that country

shelly substances, plaster or gypsum: experience and reason will prove that we ought to arrange in the same class, and by the side of the others, wood ashes, ground bones, and burnt bones. We will not place in the same list the ashes of peat, of bituminous coal, and red pyritous ashes: their effect is not owing to their lime, but, as will be seen afterward, rather to the effect of fire upon the earthy parts, and particularly upon the argil which they contain.

We shall next in order treat of manures of the sea, or saline manure of different kinds, of mixtures of earth, of calcined clay; and finally, of paring and burning turf, and the different questions which peat presents in agriculture.

1. *Of Liming—On the Use of Lime for the Improvement of Soil.*—Among the immense variety of substances, and of combinations which compose the upper layers of the globe, the earthy substances, silex, alumine, and lime, form almost exclusively the surface soil: the greater portion of other substances being unfit to aid vegetation, they ought to be very rare upon a surface where the Supreme Author willed to call forth and to preserve the millions of species of beings of all kinds, which were to live on its products.

It was also a great benefit to man, whose intelligence was to be exercised upon the surface of the soil, to have so few in number the substances proper to support vegetation. The art of agriculture, already so complex, which receives from so many circumstances such divers modifications, if there had been added new elements much more complicated, would have been above the reach of human intelligence.

2. But among these substances, the two first, silex and alumine, form almost exclusively three fourths of

use this shelly earth to improve their fields." This definition is from Rozier's *Cours Complet*, and though it clearly shows that the substance in question is the same as what is called "marl" in Virginia, it is equally clear that neither of these authors consider *fahlun* as being *marl*.—TR.

all soils; the third, the carbonate of lime, is found more or less mixed in the other fourth: all soils in which the latter earth is found, have similar characters, producing certain families of vegetables, which cannot succeed in those in which it is not contained.

The calcareous element seems to be in the soil a means and a principle of friability. Soils which contain calcareous earth in suitable proportions, suffer but little from moisture, and let pass easily, to the lower beds, the superabundance of water, and consequently drain themselves with facility. Grain and leguminous crops, the oleaginous plants, and the greater part of the vegetables of commerce, succeed well on these soils.

It is among these soils that almost all good lands are found. Nevertheless, the abundance of the calcareous principle is more often injurious than useful. Thus it is among soils composed principally of carbonate of lime that we meet with the most arid and barren, as Lousy Champagne, part of Yonne, and some parts of Berry.

3. The analysis of the best soils has shown that they rarely contain beyond ten per cent. of carbonate of lime; and those of the highest grade of quality seem to contain but from three to five per cent. Thus the analysis of Messrs. Berthier and Drapiez show three per cent. of it in the celebrated soil of the environs of Lille.

4. But all these properties, all these advantages, all these products, calcareous manures bear with them to the soils which do not contain the calcareous principle. It is sufficient to spread them in very small proportions: a quantity of lime, which does not exceed the thousandth part of the tilled surface layer of the soil, a like proportion of drawn ashes, or a two hundredth part, or even less, of marl, are sufficient to modify the nature, change the products, and increase by one half the crops of a soil destitute of the calcareous principle. This principle, then, is necessary to

be furnished to those soils which do not contain it; it is then a kind of condiment disposed by nature to ameliorate poor soils, and to give to them fertility.

5. *Ancient Date of the Use of Lime.*—Lime as it appears, has long ago been used in many countries. However, nothing proves that its effect was well known to the Greeks and Romans, the then civilized portion of mankind. Their old agricultural writers do not speak of the use of lime on cultivated lands, nor on meadows. Pliny, the naturalist, tells us, however, that it was in use for vines, for olives, and for cherry-trees, the fruit of which it made more forward; and he speaks of its being used on the soil generally in two provinces of Gaul, those of the Pictones and Ædúi,* whose fields lime rendered more fruitful. The agriculture of the barbarians was then, in this particular, more advanced than that of the Romans. After that, all trace of the use of lime in agriculture is lost for a long time—whether because it had ceased to be used, or only because the notice of it was omitted by writers on agriculture. The trace is again recovered with Bernard Pellissy, who recommends the use of it, in compost in moist lands, and speaks of his use of it in the Ardennes. Nearly a century later Olivier de Serres† advises its employment in the same manner, and reports that they made use of it in the provinces Gueldres and Juliers, in Belgium. He makes no mention of its use in France; but as the practices of agriculture were not then much brought together, and were but little known, it may be believed that at that time Flanders, Belgium, and Normandy, made use of lime.

In England, liming seems to have been in use earlier and more generally than in France. But then, and ever since, good agricultural practices have remained in the particular countries where they were establish-

* *Ædúi et Pictones calce uberrimos fecere agros.*

† Who wrote on Agriculture in the reign of Henry IV. of France.—TR.

ed, without being spread abroad. Now, novelties carry no alarm with them—and within the last twenty years liming has made more progress than in the two preceding centuries.

6. *Of Soils suitable for Liming.*—Lime, as has been said before, suits such soils as do not contain it already. To distinguish these soils from others, chymical analysis is, without doubt, the surest means; but it offers often too many difficulties, and lime may be met with in a soil in proportion great enough to exert its power on vegetation without producing effervescence with acids.* But visible characters may furnish indications almost certain. The soils where the cow-wheat [*melampyre*], rest-harrow [*l'ononis, ou arrete-bœuf*], thistles, colt's foot [*tussilage*], and red poppy, spring spontaneously—which produce well in wheat, legumes, or plants of the pea kind, and especially sainfoin—where the chestnut succeeds badly—which shows but little of dog's tooth [*chien-dent*], volunteer grasses, or common weeds [*gramines adventices*], except of the small leguminous kinds—soils which, after being dry, crumble with the first rain—all these are almost certainly calcareous, have no need of lime, nor its compounds,† and would feel from their use rather ill than good effects.

On the contrary, all soils composed of the moulderings [*debris*] of granite or schistus, almost all sandy soils; those which are moist and cold, of the immense

* This is a full though indirect admission of the truth of the doctrine of *neutral soils*, maintained in the Essay on Calcareous Manures.—TR.

† Though both the truth and the usefulness of this passage, in general, are admitted, yet it is incorrect in the position that none of the “compounds of lime” would be advantageously employed on calcareous soils. On the contrary, the sulphate of lime (gypsum), the most important compound as a manure next to the carbonate, is most effective where the land has lime in some other form; and, indeed, as has been maintained elsewhere, it seems inert and useless on soils very deficient in lime.—See *Essay on Calcareous Manures*, pp. 50, 92.

argilo-siliceous table-lands [*plateaux argilo-silicieux*] which separate the basins of great rivers;* those where rushes [*petits joncs*], the heath, *les petits carex blancs*, the whitish moss spring spontaneously—almost all the soils infested with *avoine a chapelets*, with dog's-tooth, with bent grass [*agrestis*], red sorrel, and the little feverfew—that soil where, unless so clayey as to offer great difficulty to cultivation, only rye, potatoes, and buckwheat, can be made to grow, and where sainfoin and the greater part of the crops of commerce cannot succeed—where, however, trees of all descriptions, and especially of the resinous kinds, the wood-pine, the sea-pine, the larch, the northern-pine, and the chestnut, thrive better than in the best land—all these soils are without the calcareous principle; and all the improving manures in which it is

* The character of the lands called by the author "*plateaux argilo-silicieux*," and which he refers to frequently in the course of his essay, can only be gathered from the context. They are poor, intractable under tillage, and but little pervious to water. The name indicates their composition to be siliceous and aluminous earth almost entirely. It may be inferred that such lands resemble in soil the elevated level *ridges*, which in lower Virginia separate different water-courses, and especially those which, in addition to being miserably poor, are remarkably close, stiff, and "water-holding," and are in some places called "cold livery land," "pipe-clay," or "cray-fish" soils. Soil of this kind, and of a marked character, is particularly described at page 40, Essay on Calcareous Manures, 2d ed. M. Puvis elsewhere speaks of this "argilo-silicieux" soil as being found everywhere in France, and as known in different places under the various names of "terrain blanc," "blanche terre," in the south, "boulbenne," in the north, of "terre clytre," and "terre a bois"—and in the basin of the Loire, "terre de Sologne." The last name would direct us to the lands of Sologne, which furnish it, as it may be presumed, as being of like quality. Arthur Young says, "Sologne is one of the poorest and most unimproved provinces of the kingdom, and one of the most singular countries I have seen. It is flat, consisting of a poor sand or gravel, everywhere on a clay or marl bottom, retentive of water to such a degree that every ditch and hole was full of it."—*Ta.*

found, would give to these, the qualities of, and nourish the growths peculiar to, calcareous soils.

But there, more than elsewhere, it is especially necessary to avoid too much haste. Liming upon a large scale ought not to be done, until after having succeeded in small experiments on many different parts of the ground designed to be improved.

7. *Extent of surface to which lime is suitable.*—A great proportion of the soil of France does not contain the calcareous principle. The country of primitive formation—the mountains of which the rock is not calcareous—many soils even, of which the subsoils enclose calcareous formations—the great and last alluvion which has covered the surface, and which still composes it wherever the return waters have not carried it off with them—also extensive surfaces, in the composition of which the calcareous principle had not entered except in small proportions, and which small amount has been worn out by the successions of vegetation—all these kinds of soil, which comprise at least three fourths of the surface of France, to be fertilized, demand calcareous manures. If it is admitted that one third of all this space has already received aid from lime, marl, ashes of wood, or of peat, of bones burnt, or pounded, there will still remain the half of France to be improved by such means; an immense task, doubtless—but of which the results will be still more prodigious, since it will cause the products of all this great space to be increased one half, or more.

8. *Of the various modes of applying Lime to the Soil.*—Three principal modes of proceeding are in use for applying lime. The first is the most simple, and is the most general wherever lime is obtained cheaply, and where culture is but little advanced in perfection, and manual labour is dear. This consists in putting the lime [the burnt limestone] immediately on the ground in little heaps at twenty feet average distance, and each heap containing, according to the

rate of limiting, from a cubic foot of the stone to half that quantity. When the lime has been slaked by exposure to the air, and has fallen into powder, it is spread on the surface so as to be equally divided.

9 The second mode differs from the first in this respect: the heaps of stone are covered with a coat of earth, about six inches thick, according to the size of the heap, and which is equal to five or six times the bulk of the lime. When the lime begins to swell, by slaking, the cracks and openings in the heap are filled with earth: and when the lime is reduced to powder, each heap is worked over, so as to mix thoroughly the lime and the earth. If nothing hurries the labour, this last operation is repeated at the end of fifteen days—and then, after waiting two weeks more, the mixture is spread over the soil.

10. The third process, which is adopted where culture is more perfect, where lime is dear, and which combines all the advantages of liming without offering any of its inconveniences, consists in making compost heaps of lime and earth, or mould. For this, there is first made a bed of earth, mould, or turf, of a foot, or thereabouts, in thickness. The clods are chopped down, and there is spread over a layer of unslaked lime of a hectolitre* for the twenty cubic feet, or a tun to the forty-five cubic feet of earth. Upon this lime there is placed another layer of earth, equal in thickness to the first, then a second layer of lime; and then the heap is finished by a third layer of earth. If the earth is moist, and the lime recently burnt, eight or ten days will suffice to slake it completely. Then the heap is cut down and well mixed—and this operation is repeated afterward before using the manure, which is delayed as long as possible, because the

* The hectolitre contains 6103.8 English cubic inches, or is equal to 2.82, (or about 2.6-7) Winchester bushels. Therefore the hectolitre is rather more in proportion to the hectare, than our bushel is to the acre. The decalitre is the tenth of an hectolitre, and of course the "double decalitre" is the fifth.—TR.

power of the effect on the soil is increased with the age of the compost; and especially if it has been made with earth containing much vegetable mould. This method is the one most used in Belgium and Flanders: it is becoming almost the exclusive practice in Normandy: it is the only practice, and followed with the greatest success, in La Sarthe. Lime in compost is never injurious to the soil. It carries with it the surplus of alimentary manure which the surplus of product demands for its sustenance. Light soils, sandy or gravelly, are not tired by repetitions of this compost. No country, nor author, charges lime, used in this state, with having been injurious to the soil. In short, this means seems to us the most sure, the most useful, and the least expensive mode of applying lime as manure.

11. The reduction of burnt lime to powder by means of a momentary immersion in water in handle-baskets, serves much to hasten the slacking, whether the lime is to be applied immediately to the soil, or in compost-heaps—some hours in this manner sufficing, in place of waiting two weeks; however, the effect of lime, in this state, may well be different, as we have then the hydrate of lime, and less of the carbonate of caustic lime.* If great rains follow, this process is not without its inconveniences, because then the lime, which is already saturated with water, is more easily brought to the state of mortar, which ought to be avoided more than every other injury to the manure.

The reduction of burnt limestone to powder, whether it be spontaneous or by immersion, produces in the compost a bulk greater by one half or more than that of the stone—ten cubic feet, producing fifteen—or a tun, ten cubic feet. This increase is not uniform with all kinds of lime; it is greater with the rich, [*grasses*,] and less with the poor varieties.

* An incorrect expression certainly, but literally translated.—Tr.

12. *Liming, as practised in different countries. In the Department of Aisne.*—The application of lime in Aisne dates fifty years back. At the present time, the soil which has been limed is still more productive than the neighbouring, not limed. Nevertheless, liming is but beginning to extend, while marling, which was begun fifteen years later, has already covered many thousands of hectares. This is because marling is an operation within the means of poor cultivators, being accomplished by labour alone; while liming requires considerable advances, especially in this country, where lime is dear, and the dose given is heavy.

The dressings vary in quantity, from sixty to one hundred hectolitres the hectare, according to the nature of the ground, and often according to the caprice of the cultivators. Although these limings have not been made with all the care and economy that was desirable, they have been very efficacious when the soil has been sufficiently drained. The following tables, extracted from the registers of three contiguous domains, belonging to M. Armand, three years before, and nine years during the progress of liming, give us the means of appreciating the results. The quantities of seed and of crops, are calculated in double decalitres, or in measures of fifths of hectolitres. The application of three thousand hectolitres [eight thousand four hundred and ninety bushels] of lime, of the value of six thousand francs [eleven hundred and sixteen dollars] upon thirty-two hectares [eighty acres] of ground, made successively during nine years, has more than doubled the crops of winter grain, the seed being deducted. The other crops of the farms have received a proportional increase; and the revenue of the proprietor, in doubling, has annually increased two-thirds more than the amount of the sum expended in the purchase of lime. Still, there is not yet half the arable land limed, since of sixty-six hectares, only thirty-two have received this improvement.

TABLE OF PRODUCT OF THE DOMAIN OF LA CROISSETTE.
 TABLE OF PRODUCT OF THE DOMAIN OF M. SERIAT.
 TABLE OF PRODUCT OF THE DOMAIN OF LA BARONNE.

YEARS.	RYE.		WHEAT.		YEARS.	RYE.		WHEAT.		YEARS.	RYE.		WHEAT.	
	Seed.	Product.	Seed.	Product.		Seed.	Product.	Seed.	Product.		Seed.	Product.	Seed.	Product.
1822	110	600	24	146	1822	120	487	16	109	1822	110	505	22	180
1823	110	764	24	136	1823	120	708	16	103	1823	110	643	22	138
1824	110	744	24	156	1824	120	644	18	84	1824	110	662	24	149
1825	107	406	27	251	1825	112	504	28	228	1825	102	398	32	252
1826	106	576	28	210	1826	120	677	20	115	1826	110	612	32	187
1827	100	504	30	249	1827	115	594	20	162	1827	107	546	34	204
1828	90	634	36	391	1828	118	726	40	328	1828	98	696	38	343
1829	82	538	48	309	1829	104	566	41	277	1829	84	608	40	268
1830	60	307	60	459	1830	79	298	71	477	1830	91	389	59	374
1831	78	350	40	417	1831	91	416	43	326	1831	92	411	40	295
1832	55	478	58	816	1832	79	411	75	786	1832	70	512	80	649
1833	61	529	52	545	1833	76	616	48	351	1833	75	511	51	471

The products of 1834 are still greater than those of 1833. But these are sufficient to prove the importance and utility of applying lime to suitable soils.

Many other examples sustain these results; and from them all it appears, that the wheat seedings are increased from double to triple—that the rye lands, from bringing four to five to one of seed, in rye, are

able to bring six to eight in wheat—and that other products are increased in proportion. The melioration then is, relatively, much greater upon bad ground than upon good, since it is two thirds and more on the wheat land, and on the rye lands the crop is increased in value threefold.

13. *Flemish Liming*.—The use of calcareous manures in the department of the North, and in Belgium, appears to be as old as good farming. It is now much less frequent in Belgium. The ancient and repeated limings have, as it seems, furnished to great part of the soil all that is necessary to it, for the present. But the department of the North still receives lime, marl, or ashes, everywhere, or nearly so, where lime is not a component ingredient of the soil. They distinguish in this country two kinds of liming. The first [*chaulage foncier*] consists in giving to the soil, every ten or twelve years before seedtime, four cubic metres, or forty hectolitres of lime to the hectare.* They often mix with the slaked lime, ashes of bituminous coal, or of peat, which enter into the mixture in the proportion of from a third to a half, and take the place of an equal quantity of lime. The other mode of liming [*chaulage d'assolement*], is given in compost, and at every renewal of the rotation, or upon the crop of spring grain. It is also in regular use in this country, still more than in Belgium, upon the meadows or on cold pasture lands, which do not receive the waters of irrigation. It warms the ground and increases and improves its products. The older the compost is, the greater its effect, which lasts from fifteen to twenty years, at the end of which time the dressing is renewed.

14. The limings of Normandy, the most ancient of France, are kept up in the neighbourhood of Bayeux, while elsewhere they are forbidden in the leases: however, now they go over all the surface which has

* Forty-six bushels to the acre, English or American measure.—Tr.

need of them; but in place of being applied immediately to the soil, as in the ancient method, the lime is almost always put in compost.

15. *Liming of La Sarthe.*—Of the modes of using lime, that of La Sarthe seems preferable. It is at once economical and productive, and secures the soil from all exhaustion. It is given every three years, at each renewal of the rotation, in the average quantity of ten hectolitres to the hectare,* in compost made in advance, with seven or eight parts of mould, or of good earth, to one of lime. They use this compost on the land for the autumn sowing, and placed alternately with rows of farmyard manure. This method, of which the success is greater from day to day, is extending on the great body of flat argilo-siliceous lands, which border the Loire; and it would seem that this method ought to be adopted everywhere, on open soils that permit surplus water to drain off easily. On very moist soils the dose of lime ought perhaps to be increased.

We would desire much to inculcate with force the suitableness, and eminent advantages, of using at the same time lime and alimentary manure. Here they do better still, in using at the same time a compost of lime with earth and dung. In addition, during the half century that the Manceaux have been liming, the productiveness of the soil has not ceased to increase.

16. The countries of which we have spoken, are those of France in which liming is most general. However, more than half the departments, I think, have commenced the use, and in a sixth, or nearly, it seems to be established. Doubtless, the first trials do not succeed everywhere. There is required a rare combination of conditions for new experiments, even when they have succeeded, to induce their imitation by the great mass. Still, successful results are multiplied, and become the centres of impulse, from which meliorations extend.

* Eleven and a half bushels to the acre.—T₂.

17. *English Liming*.—The English limings seem to be established upon quite another principle from that of France. They are given with such prodigality, that the melioration upon the limed soil has no need to be renewed afterward. While in France we are content to give from a thousandth to a hundredth of lime to the tillable soil, from ten to one hundred hectolitres to the hectare, they give in England from one to six hundredths, or from one hundred to six hundred hectolitres to the hectare. The full success of the method of our country might make us regard the English method as an unnecessary waste. It seems that they sacrifice a capital five, six, ten times greater, without obtaining from it a result much superior; and that without lavishing alimentary manures also afterward, the future value of the soil would be endangered in the hands of a greedy cultivator.

We will not urge the condemnation of a practice which seems to have resulted in few inconveniences. The abundance of alimentary manures which the English farmer gives to his limed soils, has guarded against exhaustion: and then, in very moist ground, they have doubtless, by the very heavy liming, made the soil healthy, and its nature seems modified for a long time to come; and such kinds, and where *humus* abounds, will take up a heavy dose of lime, and, as it seems, always without inconvenient consequences; there is then formed there the *humate of lime* in the greatest proportion, and we shall see that this combination is a great means of productiveness in the soil.*

* In this passage the author distinctly affirms the truth of the chymical combination in the soil of calcareous and vegetable (or other putrescent)—or the power of calcareous earth to fix and retain enriching matter—which is maintained in the *Essay on Calcareous Manures*, pp. 30, 31, to be the most important action of calcareous matter as an ingredient of soil. Still M. Puvis seems to attach much less importance to this than to other agencies of lime, which are considered in the *Essay* as of little value in comparison.—Tz.

18. *Surface Liming*.—In Germany, where liming and marling, like most other agricultural improvements, have recently made great advances, besides the ordinary modes of application, lime is used as a surface dressing. They sprinkle over the rye, in the spring, a compost containing eight to ten hectolitres of lime to the hectare, fifteen days after having sown clover. Also on the clover of the preceding year, they apply lime in powder, which has been slaked in the water of a dunghill, the dose being less by one half; the effect upon the clover and the following crop of wheat is very advantageous.

In Flanders, where they use lime mixed with ashes, it is especially applied to meadows, natural or artificial, and the application is then made on the surface.

19. *Burning Lime*.—The burning of lime is performed with wood, with pit coal, or with peat; in temporary kilns, or furnaces, in permanent, or in perpetual kilns. It is burnt in many places most economically with coal, but it is not so good a manure as the lime burnt with wood, because, as it seems, of the potash contained in the latter case. There are but few places in which peat is used for this purpose; however, in Prussia they succeed with three fourths peat and one fourth wood. It is, doubtless, a very economical process, and the *Société d'Encouragement* has given in its transactions plans of peat kilns; but I know not whether the operators who received prizes for their use have continued the practice.

Temporary kilns admit of the burning of a great quantity of lime; but the permanent kilns burn it with most economy of fuel. In the first, five quintals of wood burn four quintals, or one tun, or two and one fourth hectolitres of lime—and in the other, the same quantity of wood will suffice for six quintals or three and a half hectolitres. But in the permanent kilns such is the expense of construction and repairs, that they cannot be justified except when kept in frequent use. Coal burns from three to four times its bulk of

lime—the shape of the kiln, the kind of limestone, and that of the coal, making the difference. Hydraulic lime is calcined more easily than the common [*chaux grasses*]. Egg-shaped kilns for coal seem to be preferable to the conical, which are more generally met with.

20. *Precautions to be used in Liming.*—Whatever may be the method adopted for using lime, it is essential that, like all calcareous manures, it should be applied in powder, and not in a state like mortar—and upon the earth when not wet. Until the lime is covered up finally, all rain upon it ought to be avoided, which reduces it to a paste or to clots: and this injures its effect greatly, and even more than reasoning can explain. It ought not to be placed except upon soil, the surface mould of which drains itself naturally, by permitting the water to pass through. On a marshy soil, unless the upper layer has been well dried, or in a very moist soil, from which the surface water does not sink or pass off easily, the properties of lime remain as it were locked up, and do not make themselves seen, until by new operations, the vegetable mould has been drained and put in healthy condition.

On an argillaceous and very moist soil, the use of marl, which is applied in great quantities, is preferable to that of lime, because it can have a more powerful effect in giving the deficient health to the surface mould. On soil of this kind, a deep ploughing is a preliminary condition, essential to the success either of liming or marling: because in increasing the depth of the tilled soil, we increase also the means of putting the surface into healthy condition.

21. To secure the effect of lime on the first crop, it ought to be mixed with the soil some time before the sowing of the crop: however, if it is used in compost, it is sufficient that the compost be made a long time previously.

Lime, whether alone or in compost, spread dry.

upon the soil, ought to be covered by a very shallow first ploughing, preceded by a slight harrowing, in order that the lime, in the course of tillage, may remain always, as much as possible, placed in the midst of the vegetable mould.

Lime, reduced to the smallest particles, tends to sink into the soil. It glides between small particles of sand and of clay, and descends below the sphere of the nutrition of plants, and stops under the ploughed layer of soil: and when there in abundance, it forms by its combinations a kind of floor, which arrests the sinking water, and greatly injures the crops. This is an inconvenience of lime applied in heavy doses, and is hastened by deep ploughing.

22. *Various qualities of Lime.*—It is necessary for the farmer to know the nature of the lime which he uses. It may be pure, or mixed with silex, clay, or magnesia. *Pure lime* is the most economical, the most active, that which can produce the most effect in the least quantity.

Siliceous limestone is used in greater quantity. The lime from it receives, as does the foregoing, the name of *hot lime*, and there is little difference in the application, except that more of the latter is wanting.

Argillaceous lime is the same as the hydraulic lime, or the *poor lime* of builders. It appears that the first two kinds are more favourable to forming grain, while the latter favours more the growth of straw, grasses, and leguminous crops. It is better for the improvement of the soil, but a heavier dose of it is required.

Magnesian lime acts very powerfully, but exhausts the soil if given in a large dose, or if it is not followed by alimentary manure in abundance. It has exhausted some districts in England, and entire provinces of America,* and it is to this kind that seem due most of the complaints made against lime.

* The author has been deceived by exaggerated accounts of injury from liming in America. It is probable that wherever it occurred it was caused by the usual ignorance of the action

By chymical processes the farmer may make himself sure of the nature of the lime which he uses.

Pure lime is commonly white, and is dissolved, without anything being left, in nitric or muriatic acid.

Silicious lime is often gray, and leaves a sandy residue after solution, which is rough to the touch.

Argillaceous lime is obtained from stones which have a clayey odour and appearance: it is commonly yellow; and leaves, after the solution, a residue which is mostly an impalpable powder [*et qui prend en masse*], which may be formed into a mass when wet.

Magnesian lime is made from stone commonly coloured brown or pale yellow; it forms a white cloud in nitric acid, diluted with water, and used in less quantity than sufficient for saturation.

23. *Of second limings.*—When the limed field returns to the state in which it was before the operation, when the same weeds reappear, and the crops lower in product, it is time to renew the application of lime. It may be conceived that the time of the second liming depends on the amount given in the first. When the dressing has been light, it is necessary, as is done by the Flemings and the Manceaux, to recommence entirely, or to the extent of the first dressing: when it has been heavy, the next may be diminished by one half. Besides, in this matter we should take counsel of the state of the soil and of experience, because there are some lands which demand, and can use heavier doses of lime than others.

24. *Quantities applied.*—The quantities of first as of second dressings of lime, vary with the consistence of soils: they ought to be small on light and sandy soils—and may without ill consequences, be heavy on clay soils.

of lime: from erroneously considering it as alimentary, and directly fertilizing manure, and after applying it, wearing out the soil by continued grain crops. Such effects are spoken of by Bordley.—Tr.

The dose ought to vary according as the soil is more or less pervious to water, or as drained well or ill by its texture. Small applications to soils from which the superfluous water does not pass easily, are but little felt; but if the dressing is heavy, and the ploughing deep, the lime aids the draining and adds to the healthy state of the soil. It may be conceived that the quantity of lime ought also to be increased with the annual quantity of rain that falls—because in proportion to that quantity ought the openness of the soil, and its fitness for draining, to be extended.

Nevertheless, the practices of the departments of the North and of La Sarthe seem to indicate the average dressing which suits in general for land: thus the liming of the North, which every ten or twelve years gives to the soil forty hectolitres of lime to the hectare, or a little more than three hectolitres a year, agrees with that of La Sarthe, which gives eight or ten hectolitres every three years. The first plan gives at one dressing what the other distributes in four: as both make a like average, it may be thence inferred that the earth demands annually three hectolitres, or three hundred, twenty-three bushels to the acre, to sustain its fecundity. But as neither the soil nor the plants consume all this quantity of lime, it is to be believed that at the end of a greater or less length of time, the soil will have received enough to have no more need of it for a certain space of time.

25. *Manner of treating limed lands.*—After having, by liming, given the soil a great productive power, having put it in condition to produce the most valuable crops, which are often also the most exhausting, it is necessary to husband these resources—to give manure in return for the products obtained—to employ as litter, and not as food, the straw, now increased by one half—to raise grass crops from the soil now fitted to bear them with advantage—in short, to modify the general plan, and the detail of the culture ac-

cording to the new powers of the soil, the prices of commodities, and to local conveniences.

However, it is not necessary to hurry the change of the rotation. Such an operation is long, difficult, very expensive, and ought not to be executed but with much deliberation.

26. *Effects of lime on the soil.*—The effects of lime, although similar to, are not identical with, those produced by marl; and the qualities of soils limed, differ in some points from those of natural calcareous soils. The grain from limed land is rounder, firmer, gives less bran, and more flour, than that from marled land: the grain of marled land is more gray, gives more bran, and resembles that made upon clover, though it may be preferable to the latter. The grain of a limed soil is more like that from land improved with drawn ashes. Limed land is less exposed to danger from drought than marled land, on soils naturally calcareous. The crop is not subject to be lodged at flowering time, when the sowing was done in dry earth.

27. In limed earth, weeds and insects disappear. The earth, if too light, acquires a stiffness, and is lightened if too clayey. The surface of the argillo-siliceous soil, before close and whitish, is made friable, and becomes reddish, as if rotten: it hardens and splits with drought, and is dissolved by the rains which succeed. This spontaneous loosening of the soil facilitates greatly the labour of the cultivator, the movement of the roots of the growing plants, and the reciprocal action of the atmosphere upon the soil, which remains open to its influence.

All these new properties which the limed soil has acquired, doubtless explain in part the fertilizing means which calcareous agents bring to the soil: but we think it is still necessary to seek some of these causes elsewhere.

28. Lime, according to the recent discoveries of German chymists, seizes in the soil the soluble hu-

mus or humic acid, takes it from all other bases, and forms a compound but slightly soluble, which appears, under this form, eminently suitable to the wants of plants. But as this compound is not soluble in less than two thousand times its weight of water, while without the lime the humus is soluble in a volume of water less by one half, it would follow that, in consequence of lime, the consumption of this substance, and the productive power of the soil would, in like proportion, be better preserved. Since the products of the soil increase much from the liming, while the humus is economized, since these products borrow very little from the soil, which remains more fertile while thus yielding greater products, it follows that the principal action of the lime consists, at first, in augmenting, in the soil and in the plants, the means of drawing from the atmosphere the vegetable principles which they find there; and next, in aiding, according to need, the formation, in the soil or the plants, the substances which enter into the composition of plants, and which are not met with ready formed either in the atmosphere or in the soil.

The researches upon these various points are curious, important, interesting to practice as well as to science—and will lead us to explain, by means not yet appreciated, the action of lime upon vegetation.

29. *Absorption by plants of the principles of the atmosphere, in the vegetation on uncultivated soils.*—Saussure has concluded, from his experiments, that plants derive from the soil about one twentieth of their substance; and the experiments of Van Helmont and of Boyle have proved that considerable vegetable products diminish very little the mass of the soil. But this fact is still better proved by the observation of what passes in uncultivated soils.

Woodland that is cut over in regular succession (*taillis*) produces almost indefinitely, without being exhausted, and even becoming richer, the mass of vegetable products which man gathers and removes,

and of which the soil does not contain the principles. If, instead of woodlands thus partially and successively cut over, we consider upon the same soil a succession of forests, and for greater ease of estimation, resinous forests, we find for the products of the generation of an age, forty to fifty thousand cubic feet to the hectare. This product is less than that of the resinous forests of many parts of the country, and yet it is nearly equal in bulk to half of the layer of the productive soil itself: it represents an annual increase of twenty-four thousand weight of wood to the hectare—and which is produced not only without impoverishing, but even while enriching the soil, by an enormous quantity of droppings and remains of all kinds.

These products which do not come from the soil, are then drawn from the atmosphere, in which plants gather them by means of particular organs designed for that use. These organs are the myriads of leaves which large vegetables bear—aerial roots, which gather these principles either ready formed in the air, or which take up there the elements, to combine them by means of vegetable power. But these aerial roots exert quite a different and superior energy in gathering the constituent principles of plants in the atmosphere, to that of the roots in the ground—since the former furnish nearly the whole amount of the vegetable mass, while the latter draw but very little from the soil.

30. Plants may well find in the atmosphere the greater part of the *volatile* principles which compose them—the carbon, hydrogen, oxygen, and azote. But it is not so easily seen whence they obtain the *fixed* principles of which their ashes are composed. These products could not exist ready formed in the soil—for the saline principles contained in the ashes of a generation of great trees, which would amount to more than twenty-five thousand weight to the hectare, would have rendered the soil absolutely barren, since, according to the experiments of M. Lecoq of Clermont,

the twentieth part of this quantity is enough to make a soil steril. We would find a similar result in accumulating the successive products of an acre of good meadow. It is then completely proved that the saline principles of plants do not exist ready formed in the soil. They are no more formed in the atmosphere, or the analyses of chymists would have found them there. However, as the intimate composition of these substances is not yet perfectly known, their elements may exist in the atmosphere, or even in the soil, among the substances which compose them.

Neither can it be said that these salts may be derived from the atomic dust which floats in the air; for this dust is composed of fragments organic and inorganic, carried especially to the plants themselves, and then, in estimating this atomic matter at the most, we shall scarcely find in it the hundredth part of the saline substances contained in the vegetable mass produced. We ought then to conclude that the saline substances of plants are formed by the powers of vegetation or of the soil.

In like manner as with the saline principles, the lime and the phosphates which are formed in ashes ought to be due to the same forces, whether the roots take up their unperceived elements in the soil, or the leaves gather them in the atmosphere. This consequence results evidently from this fact—that plants grown in soils, of which the analysis shows neither lime nor the phosphates, contain them notwithstanding in large proportion in their fixed principles—of which, or of the ashes, they often compose half the mass.*

32. *Absorption of plants, in vegetation on cultivated soils.*—Vegetation on uncultivated soils operates under conditions altogether different from those of the cul-

* This fact is explained very different by the Essay on Calcareous Manures (ch. vii.) where it is used to sustain the doctrine of neutral soils.—TR.

tivated, so that the results receive modifications which it is important to examine.

Nature produces, and continues to produce all the vegetable mass in spontaneous growth, without any other condition than the alternation and succession of the species. In vegetation on cultivated land, by bringing together the same individual plants which are to grow abundantly on a soil and in a climate which, in most cases, are not those which nature had designed, there are required, besides the general condition of alternation of the species, frequent tillage of the soil, and means to repair its losses, that the culture may be productive and be continued. However, with these new conditions, the force of absorption of plants on the atmosphere still furnishes the greater part of the vegetable principles in soils not limed—and still more in limed soils.

To form a precise idea, we will take it in the land of the writer, its culture and its biennial rotation. As the same qualities of soil are found elsewhere, as no particular circumstance increases or impairs its products, there would be found similar results, for the same qualities of soil, with a different culture. The inferences which we will draw from ours will apply then to all others.

On our soil of the third class, or worst quality, fallow returns every two years, with a biennial manuring of one hundred and twenty quintals to the hectare. This mass contains more than four fifths of water, which should not be counted as manure, and consequently the substance which serves for the reparation of the soil is reduced to twenty-four quintals. We reap, in rye, straw, and buckwheat, after the year of fallow, a dry weight of forty to fifty quintals on an average. If it is supposed that all the manure is consumed, or employed in forming vegetable substance, still the soil would have furnished eighteen to twenty quintals more than it received, and which excess would

be due to the power of absorption, whether of the soil or of the plants, on the atmosphere.

On land of middle quality, which yields a crop every year, with a double manuring, that is to say, of forty-eight quintals of dry manure, in two years there is a product of wheat, maize, or potatoes, which amounts to from twelve to fifteen thousand weight, one hundred and twenty to one hundred and fifty quintals, of which two thirds, or eighty quintals at least, are derived from absorption.

On soils of good quality, with a manuring of one third more than the last, which is equal to sixty-four quintals of the dry substance to the hectare, there are obtained of dry products, in grain, straw, roots, or hay, double of the last, or nearly so, of which three fourths, or one hundred and eighty quintals, are due to the power of absorption.

Lastly—upon the most fertile soils (*sols d'exception*), where manures are useless, the product, often double, or at least half as much more than the last-mentioned, will amount to three hundred and sixty quintals to the hectare in two years. This product would be, as in spontaneous vegetation, entirely due to absorption.

We would have, then, to represent the products of two years, in quintals, in the four classes of soil under consideration, the progressive amounts of forty-two, one hundred and thirty, two hundred and forty, three hundred and sixty; or, by deducting from these products the weight of the manure, we would have, to represent the power of absorption, the progression eighteen, eighty-two, one hundred and seventy-six, three hundred and sixty quintals. From this is deduced, as the first conclusion, that, supposing the plants have consumed and annihilated all the substance of the manure given, (which is beyond the truth), plants receive a much greater part of their substance from the atmosphere than from the soil; and that this

power of drawing food from the atmosphere increases with the goodness of quality in soils.

33. The proportion of fixed substances, or ashes, in agricultural products, is forty-three pounds to one thousand, and consequently, in our four classes of land, the quantity amounts to one hundred and eighty, five hundred and fifty-nine, ten hundred and thirty-two, one thousand five hundred and forty-eight pounds. But the soluble saline substances form at least half of these ashes: they are then produced in the two years of the rotation, in the quantities of ninety, two hundred and seventy-nine, five hundred and sixteen, seven hundred and seventy-four pounds. But, according to Kirwan, barnyard manure yields two per cent. of soluble salts: then the manure given to these soils contained forty-eight, ninety-six, one hundred and twenty-eight pounds of saline substances, which, being deducted from the preceding quantities, leave the four classes of soils stated, forty-two, one hundred and eighty-three, three hundred and eighty-eight, seven hundred and seventy-four pounds of products in soluble salts, in two years of the rotation, gained solely by the absorbing forces of the soil and of plants.*

34. But, in the same soils, with the same manures and the same tillage, by the addition to the thickness of the ploughed layer of only one thousandth part of lime, the products, whether volatile or fixed, are increased in a striking manner: the soil of the first-named, or lowest, quality reaches the product of the second—the second rises one half or more—and that of the best, of the manured soils, increases a fourth. Thus, our scale of product becomes 130, 200, 300 quintals—and deducting the manure, 106, 152, 236 quintals, for the two years of the rotation. The most fertile soil (*sol d'exception*) cannot receive lime beneficially,

* The proportions of ashes of different plants, and of their saline matters, vary greatly—and the uniform proportions assumed above, are far from correct, even as averages of unequal proportions. This will sufficiently appear from the

because it contains it already; these lands all belong to alluvions, where the calcarous principle has almost always been found in greater or less proportion.

35. The product of fixed principles (as ashes) in the three classes of limed soils, would be 559, 868, 1290 pounds, and in soluble salts 278, 430, 645 pounds; and, deducting the soluble salts of the manure, the quantities would be 230, 334, 535. A light addition of lime has then doubled the force of absorption, and almost

following examples extracted from Saussure's table of the products of various vegetable substances.—*See Davy's Ag. Chym. Lec. III.*

Constituents of one hundred parts of ashes.

Names of Plants.	Ashes from 1000 parts dry.	Soluble Salts.	Earthy Phosphates.	Earthy Carbonates.	Silicia.	Metallic Oxides.	Loss.
Wheat, in flower,.....	—	43,25	12,75	0,25	32	0,5	12,25
Do. seeds ripe,.....	—	11	15	0,25	54	1	18,75
Do. seeds ripe,.....	33	10	11,75	0,25	51	0,75	23
Straw of wheat,.....	43	22,5	6,2	1	61,5	1	78
Seeds of do.	13	47,16	44,5	—	0,5	0,25	7,6
Bran, ...	52	4,16	46,5	—	0,5	0,25	8,6
Plants of maize, (Ind. corn)							
a month before flowering,	122	69	5,75	0,25	7,5	0,25	17,25
Do. in flower,.....	81	69	6	0,25	7,5	0,25	17
Do. seed ripe,.....	46						
Stalks of do.	84	72,45	5	1	18	0,5	3,05
Spikes (tassels,) of do.....	16						
Seeds of do.	10	62	36	—	1	0,12	0,88
Oats (entire plant,)	31	1	24	—	60	0,25	14,75

The proportion of soluble salts, two per cent. found by Kirwan in barn-yard manure, however correctly ascertained in a particular case, can no more be relied on as a fixed and uniform proportion, or even a true general average, as used by M. Puvis in the estimates above.—*Tr.*

tripled the quantity of saline principles produced. One of the most remarkable effects of lime consists then, in making a soil produce a much greater proportion of saline principles: and if the experiments of M. Lecoq upon the efficacy of saline substances on vegetation are to be admitted, it would be in part to the phenomenon of their production that lime would owe its fertilizing effect.

36. It results from what precedes, that salts are formed in the soil or in vegetables: thus we see every day the nitrates of potash and of lime form under our eyes in the soil, or elsewhere, without anything indicating to us the origin of the potash which is contained. But potash itself again forms spontaneously in drawn ashes, according to the observations of the chymist Gelhen. We see salts also renewed in the artificial nitre beds, with the aid of moisture and exposure to the air. But it is the presence of lime that determines this formation more particularly. The nitrates abound in the ruins of demolished edifices; they are formed in the walls, and in all parts of houses situated in damp places; they effloresce on the buildings of chalk in Champagne; they are produced spontaneously in the ploughed lands of the kingdom of Murcia. This effect, which we see that the calcareous principle produces everywhere, we think it produces in all the soils to which it is given, and where meet the circumstances which favour the formation of nitrates, viz.: humidity, vegetable mould, and exposure to the air. But, according to the experiments of M. Lecoq and others, and the opinion which is established of the old agriculturists, the nitrates are the most fertilizing salts. It would be then to their formation, which it promotes in the soil, that lime owes, in part, its effect on vegetation.

37. The foregoing proofs of the daily formation in the soil, and by vegetable life, of saline and earthy compounds, taken in nature and on a great scale, are doubtless sufficient: but they may still be supported

by the experiments and opinions of able men who have adopted the same system.

And first—in the experiment of Van Helmont, in five years, a willow of five pounds grew to weigh one hundred and sixty-nine, and had caused a loss of only two ounces to the soil which bore it. But the one hundred and sixty-four pounds which the willow had taken contained five pounds of ashes, which are due entirely to absorption, since the leaves and the other droppings of five years, which were not saved, would have given at least one pound of ashes, which makes up for, besides all that which, in spite of the sheet of lead which covered the top of the vessel in which the willow grew, it might have received in the waterings, and from other fortuitous circumstances. Boyle has repeated and confirmed this experiment in all its parts.

Lampadius, in different isolated compartments, some filled with alumine, others with silex, others with carbonate of lime, all pure, has made plants to grow, of which the burning has yielded to analysis like results; and which, consequently, contained earths which were not in the soils which bore them.

Saussure, in establishing that plants do not take in the soil more than a twentieth of their substance, in extract of mould and in carbonic acid, has necessarily established, by the same means, that almost the whole amount of fixed principles do not proceed from the soil.

Braconet has analyzed lichens, which contained more than half their weight of oxalate of lime—and he has observed others covered with crusts of carbonate of lime when there was none of this earth in the neighbourhood.

Shrader, in burning plants grown in substances which did not contain any earthy principle, has found in their ashes, earths and salts which were neither in the seeds sown, nor in the pulverized matters in which the plants grew.

Lastly, the analyses of Saussure, though showing more of the carbonate of lime in the ashes of plants which grew on calcareous soils than on soils not calcareous, yet, nevertheless, they have formed more than a sixth of the ashes from vegetables on siliceous soils—and Einhoff has found sixty-five per cent. of lime in the ashes of pines grown on siliceous soil.* The labours of science then confirmed what we have established, that plants, or the soil, form salts and earths.†

* It is presumed, from the context, that these siliceous soils were not the least calcareous—[Ed. F. R.]

† Van Helmont's experiment, cited first in the list above, like M. Puvis's reasoning in general, furnishes ample proof that most of the volatile parts of vegetables, and the greater part of their bulk, are drawn from the atmosphere—and they are equally defective in proving that earths and other fixed principles are thence derived, or are formed by the power of vegetable life. Distilled water is not entirely free from earthy matter, and if it had been used for watering the willow, it would in five years have given some considerable part of the five pounds of solid matter in the ashes. But as we are not told that it was either distilled or rain water, it may be inferred that the comparatively impure water of a fountain or stream, was used for watering the plant, and which would more than suffice in so long a time to convey the whole increase of earthy and saline matter. The experiments of Lamiadius and Shrader are liable to the same objection—and the former to this in addition—that his earths were deemed absolutely pure, when, in all probability, they were not so—and that a very slight admixture of other kinds with each, would furnish the minute quantity that a small plant could take up during its short and feeble existence under the circumstances stated. The results stated of the experiments of Braconet, Saussure, and Einhoff, may be, and probably are, entirely correct—but they are fully explained by the doctrine of neutral soils, and need no support from, and give none to, our author's doctrine of the formation of lime by vegetable power.

But though deeming M. Puvis altogether wrong in this, his main and most labored position, and that the proofs cited above, as well as some others in the preceding section, are of no worth, still these pages which present his theory, contain what is of more value. He places in a strong point of view the important truth that the atmosphere is the great treasury

38. The fertilizing effect of fallow, or ploughing, of moving and working the soils, prove still more that all these circumstances determine the formation of fertilizing principles, and probably of saline principles, in all the parts of the soil which receive the atmospheric influence.

But salts are also formed in plants. The nitrate of potash, which takes the place of sugar in the beet—the oxalate of potash, so abundant in sorrel—the carbonate of potash in fern, in the tops of potatoes, and in almost all vegetables in the first period of their life—the sulphate of potash in tobacco—the nitrate of potash in turnsol and in pellitory—prove, without reply, that vegetation forms salts, as it forms the proper juices of plants, since the soil contains the one kind no more than the other. But can we say where plants take the elements necessary for all these formations? They can take them only in the soil by means of their roots, or in the atmosphere—in the soil, which would itself take them from the atmosphere, in proportion to the consumption of plants—or directly in the atmosphere by means of their leaves, which would there gather these elements. And if the analyses of the soils, and of the atmosphere, show almost none of these elements, it will be necessary to conclude from it that the substances which analysis has found there, are themselves, or would furnish, if decomposed, the elements of the saline substances, although science may not yet have taught us the means of reaching that end.

39. The formation of lime, like that of the saline principles necessary to plants, is an operation which of nature, from which nature doubles and trebles the amount of all the small portions given to the earth by the industry of man. The author's scale of actual products from different grades of soil is also interesting. It sustains the position assumed in the *Essay on Calcareous Manures*, that the worst soils are limed, or made calcareous, to most profit—and that alimentary manures, when needed, are most productive on the best soils.—*Ed. Far. Reg.*—See p. 172.

employs all the forces of vegetation—and these forces, directed to this formation, have no energy left to give a great development to plants: but when the vegetable finds the calcareous principles already formed in the soil, it makes use of them, and preserves all its forces to increase its own vigor and size.

It would then result, from all that has been said, that lime modifies the texture of the soil—makes it more friable—invigorates it—renders it more permeable—gives it the power to better resist moisture as well as dryness—that it produces in the soil the humate of lime which encloses a powerful means of fertility—that lime increases much the energy of the soil and of plants to draw from the atmosphere the volatile substances of which plants are composed, oxygen, hydrogen, carbon, and azote—that the limed soil in furnishing to plants the lime which they need, relieves the soil and plants from employing their powers to produce it—and finally, that lime promotes the formation of fixed substances, earthy or saline, necessary to vegetables. All this whole of reciprocal action and reaction of lime, on the soil, plants, and atmosphere, explains in a plausible manner its fertilizing properties. We seem, consequently, to have nearly arrived at the resolving of an important agricultural problem, upon which were accumulated so many doubts.

40. *The amount of lime taken up by vegetation.*—The ashes of plants from calcareous soils, or those which have been made so by manures, contain thirty per cent. of the carbonate and phosphate of lime, which, by taking off the crop, is lost to the soil. But the product of limed land of middle quality, is during the two years of the course of crops, about twenty thousand pounds of dry products to the hectare, which contain a little less than a hectolitre of lime in the calcareous compounds of the ashes. The vegetation has then used half a hectolitre a year. But we have shown that there was necessary, on an average,

three hectolitres per hectare each year. Vegetation then does not take up, in nature, but a sixth of the lime which is given profitably to the soil; the other five sixths are lost, are carried away by the water, descend to the lower beds of earth, are combined, or serve to form other compounds, perhaps even the saline compounds, of which we have seen that lime so powerfully favours the formation. Another portion, also, without doubt, remains in the soil, and serves to form this reserve, which in the end dispenses, for many years, with the repetition of liming.

41. *Of the exhaustion of the soil by liming.*—"Lime," it is said, "only enriches the old men: or it enriches fathers and ruins sons." This is indeed what experience proves, when, on light soils, limed heavily, or without composts coming between, successive grain crops have been made without rest, without alternations of grass crops, or without giving to the soil alimentary manures in suitable proportion. It is also what has happened when magnesia, mixed with lime, has carried to the soil its exhausting stimulus. But when lime has been used in moderation—when, without overburdening the land with exhausting crops, they have been alternated with green crops—and when manure has been given in proportion to the products taken off—the prudent cultivator then sees continue the new fecundity which the lime has brought, without the soil showing any sign of exhaustion. Nowhere has there been complaint made of argillaceous soils being damaged by lime; and the productiveness of light soils is sustained in every case that the lime was used in compost.

In America, where the lime of oyster-shells has taken the place of that of magnesian limestone, the complaints of the exhausting effects of lime have ceased.

42. *Healthiness given to the soil and to the country by calcareous agents.**—The unhealthiness of a coun-

* There was no position in the Essay on Calcareous Ma-

try is not caused by the accumulation of water, nor from soil being covered by water. Places on the borders of water do not become sickly except when the water has quitted some part of the surface which it previously overflowed, and the summer's sun heats the uncovered soil, and causes the decomposition of the remains of all kinds of matter left by the water, and contained in the upper layers of the soil. Thus, ponds are not unhealthy except when drought, by lowering the waters, leaves extensive margins bare, to be acted on by the sun and air. In rainy years, fevers on the borders of ponds are rare.

Epidemic diseases most often arise on the borders of marshes laid dry—in the neighbourhood of mud thrown out of ditches or pits—and in the course of bringing new land into cultivation, where the ploughed soil is for the first time exposed to the summer's sun. In the interior of Rome, the vineyards, the gardens, are remarkably unhealthy—while the sickness disappears where the emanations from the soil are prevented by buildings. In the Pontine marshes, they cover the dried parts with water to arrest the danger of their effluvia. It is then from the soil, and not from the waters at its surface, that insalubrious emanations proceed. Waters placed on the surface, always in motion, agitated by every wind, are not altered in

nures which its author assumed with so much hesitation as the agency of those manures in removing causes of disease. That hesitation did not arise from doubt of the truth of the position—but because of its very high importance and its entire novelty—its being then sustained but by few known facts furnishing direct evidence, and by no known authority whatever of earlier writers. It is therefore the more gratifying to find in the work now presented, that about the same time, another and far remote investigator of the same subject, by a different course of reasoning, and by different proofs, had arrived at precisely the same conclusion—and that he maintains, even more generally than the former work, the important and sure effects of calcareous manures in rendering a country more healthy.—*Tr.*

quality, and do not become unhealthy; but whenever they are contained in some place without power to receive exterior influences, or to have motion, they are altered in their odour, taste, and consequently injured in relation to health.

Whenever water then, without covering the soil, penetrates the upper layer without being able to run through the subsoil, it remains without motion, and stagnant, within the soil—is changed by the summer's sun, serves to hasten the putrefaction of the broken-down vegetable remains in or on the mould, and the exhalations from the ground become unhealthy. Thus are all drained marshes, of which the surface only is dry, while the water still penetrates the subsoil—thus, all the margins of rivers which have been covered by recent inundations of summer, are unhealthy; thus also, (for a great and unhappy example,) the argilo-siliceous plateaux, whenever the closeness of the subsoil does not let the water pass through, produce, in dry years, at the close of summer, emanations which attack the health of the inhabitants.

43. But this unhappy effect appears almost nowhere in calcareous regions: the margins of lakes and ponds there situated do not produce the same unhealthiness, and even the marshy grounds there are less unhealthy.

The waters which spring out of, or run over calcareous beds, are always healthy to drink. The borers of Artesian wells are anxious that the water which they obtain, to be good, may come out of the calcareous strata which they go through. When the waters which hold carbonate of lime in solution in carbonic acid* run over the surface, they give health to the

* As in limestone water, lime with the greatest proportion with which it can combine of carbonic acid, (forming super-carbonate of lime,) is soluble in water. The excess of acid is lost by heat, by exposure to air, &c., and then the lime is in form of carbonate—and being insoluble in water, falls separate to the bottom.—TR.

meadows, in changing the nature and quantity of the products.

Linnæus thought that the unhealthiness of most countries depended upon the nature of the water, and was owing to the argillaceous particles which they contain; now these argillaceous particles are always precipitated by the calcareous compounds. For this reason, the waters which stand upon, or run over marl or calcareous rock, are almost always limpid and clear, because the argillaceous particles have been precipitated by the effect of the solution in the water of the calcareous principle, which is itself dissolved by an excess of carbonic acid.

We are not far from believing then, that throwing rich marl, or limestone, into a well of muddy and brackish water, might have the effect, in part at least, of clearing it, and making it healthy to drink. This remedy, if it should not be as useful as we think, at least could not produce any injury.

Lime, in all its combinations, destroys the miasmata dangerous to life. Its chloride annihilates all bad odours, arrests putrefaction, and in short, has subjected the plague of Egypt to the skill and courage of Parisot. The white-wash of lime upon infected buildings, upon the walls and mangers of stables, is regarded as serving to destroy the contagious miasmata of epidemic and epizootic diseases.

Lime destroys the plants of humid and marshy soils, and makes those suitable to better soils spring up: then its effect is to give healthiness or vigour to the soil, to dry it, and make it more mellow and permeable. The water then is no longer without motion, and altered consequently in its condition. The limed soil then, to the depth it is ploughed, ought to change the nature of its emanations as well as its products: and if the lower strata or subsoil, send up emanations, these effluvia, in passing through the improved layers of soil, where the calcareous agent is always at work and developing all its affini-

ties, ought also to be modified, and take the character of those of the upper bed. The limed soil then, it would seem, ought to be made healthy.

But what we maintain here by induction, by reasoning, is fortunately a fact of extensive experience. Among all the countries in which lime has carried and established fertility, there is not cited, that I know of, a single one where intermittent fevers prevail—while they have never disappeared in a country even where an active culture draws good products from the impermeable argilo-siliceous soil.

44. To extend the great benefit of healthiness to the whole of a country, it is no doubt necessary that the whole country should receive the health-giving agent. However, on every farm, in proportion as liming is extended over its surface, the chances of disease will be seen to diminish—and the healthiness of the country will keep pace with the progress of its fertility.

45. *Result of the use of improving manures on the soil of France in general.*—Three fourths of the whole territory of France, to be rendered fruitful, have need of calcareous agents. If the third of this extent has already received them, (which we believe is above the truth,) upon the other two thirds, or the half of the whole, the agricultural products, by this operation, would be increased one half or more, or one fifth of the total amount. But agriculture, in enriching itself will increase its power, its capital, and population; and will naturally carry its exuberant forces, its energy and activity to operate on the greater part of the seven millions of hectares of land now [*en friche*] untilled, waste, and without product. By bringing these lands into cultivation and fertilizing them by liming, or by paring and burning the surface, they would be made to yield at least one sixth of the total product. The gross product of the French soil, then increased by a third or more, might also give employment and sustenance to a population one third

greater than France now possesses ; and this revolution due successively to the tillage of the soil, to annual improvements keeping pace with the progressive increase of crops, would be insensible. The state would grow in force, in vigor, in wealth, in an active and moral population, which would be devoted to peace, and to the country, because it would belong to this new and meliorated soil. And this great result would be owing simply to applying calcareous manures to the extent of the soils of France which require them !

46. Upon our extent of fifty-four millions of hectares, our population, increased to forty-four millions, would have for each, one hectare and a quarter, and would be less confined than the twenty-four millions of inhabitants of the English soil, who have only one hectare to the head ; and yet our soil is as good, and it is more favoured by climate. And then our neighbours consume in their food at least a fourth or fifth of meat, while only one fifteenth of the food of our population consists of meat ; and as there is required twelve or fifteen times the space to produce meat as bread, it follows that twice the extent of soil is necessary to support an Englishman as a Frenchman. Hence it results, that with an increase of one third, our population would still have a large surplus product which would not exist in England, with an equal increase of population and equal increase of products of agriculture.

But this prosperity of the country, (yet far distant, but toward which, however, we shall be advanced daily,) would be still much less than in the department of the North, where a hectare nearly supports two inhabitants. And yet they have more than a sixth of their soil in woods, marshes, or unproductive lands ; they have, besides, another sixth, and of their best ground, in crops of commerce, which consume a great part of their manure, and which are exported almost entirely. This prodigious result is, without doubt,

owing in part to a greater extent of good soil than is found elsewhere; but it is principally owing there, as well as in England, to the regular use of calcareous manures. As we have seen, more than two thirds of that country [the North] belongs to the class of soils not calcareous, to the argilo-siliceous plateaux, and it makes use of lime, marl, or ashes of all kinds.

47. After this great result of increased productiveness, that upon health, although applied to the least extents of surface, would be most precious. Upon one sixth of our country the population is sickly, subject to intermittent and often fatal fevers, and the deaths exceed in number the births. Well! upon this soil without marshes, calcareous manures would bring a growing population, more numerous than that of our own healthy parts of the country—and as labour would offer itself from every side, these regions, made healthy, would soon be those where the people would be most happy, the richest, and the most rapidly increasing in numbers.

48. If we are not under an illusion, the calcareous principle and its properties upon the soil, form the great compensation accorded by the Supreme Author to man, in condemning him to till the earth. Three fourths of our soil seem not to produce, except by force of pain and labour, the vegetables absolutely necessary for man. On all sides, and often beneath this surface so little favoured, is found placed the substance necessary to the soil to render it as fertile as the best ground, to enable the cultivator to use for his profit the vegetable mould which it contains and which has been accumulating for ages—and to cause the entire soil to be covered by a population active, moral, and well employed. And this precious condiment, this active principle of vegetation, is only needed to be applied in small proportions, to obtain products of which the first harvest often compensates for all the labour and expense. And to complete the benefit, insalubrity, which afflicts the infertile soil, disappears;

the new population finds there at the same time, strength, riches, and health. Here, without doubt, is one of the most happy harmonies of the creation, one of the greatest blessings with which the Supreme Author has endowed the laborious man who is devoted to the cultivation of the earth.

OF STIMULATING MANURES.

(Continued from Article II., p 183.)

Gypsum, &c.

The employment of gypsum, or plaster of Paris, as a manure, and more especially for artificial meadows, is one of the most valuable improvements that has as yet been made in husbandry; and it is coming into general use in many parts of Europe.* It has likewise been introduced into America, where its application to the purposes of agriculture was made known by the celebrated Franklin, on his return from Paris. This distinguished philosopher, with a view of affording to his countrymen ocular demonstration of the fertilizing effects of this substance, strowed a portion of it in a pulverized state, upon a clover field bordering on one of the principal avenues to the city of Washington, and in such manner as to form the following sentence, *This has been plastered*. So astonishingly luxuriant was the vegetation where this operation had been performed, that it became a matter of general comment, and everywhere people were seen testing in a similar way, the virtues of plaster. Volumes written expressly to recommend it, would not have effected so speedy a revolution;

* Great difference of opinion has prevailed among agriculturists with respect to the uses of gypsum. It has been advantageously used in Kent, and various testimonies in favour of its efficacy have been laid before the Board of Agriculture by Mr. Smith. In America it is employed with signal success; but in most counties of England it has failed, though tried in various ways and upon different crops.—*Davy's El. Ag. Chym.* p. 306.

and from that time the Americans commenced importing large quantities of plaster of Paris.

Nevertheless, in some countries where plaster has been tried, it has failed to exhibit any fertilizing power; which leads to the conclusion that the soils in those countries contain it naturally, and that, for this reason, no sensible effect is produced by applying to them an additional quantity; and what seems to confirm this theory is the fact that such soils have actually, on analysis, been found to contain this substance as one of their constituent principles.*

Plaster is a compound of sulphuric acid and lime, containing also more or less of the water of crystallization.† A moderate degree of heat deprives it of its water, and renders it opaque; when it may be reduced to a powder, and used in this state. Although plaster, when prepared in this way, eagerly absorbs

* The reason why gypsum is not generally efficacious, is probably because most cultivated soils contain it in sufficient quantities for the uses of the grasses. In the common course of cultivation, gypsum is furnished in the manure; for it is contained in stable dung, and in the dung of all cattle fed on grass; and it is not taken up in corn crops, or crops of peas and beans, and in very small quantities in turnip crops; but where lands are exclusively devoted to pasturage and hay, it will be continually consumed. I have examined four different soils, cultivated by a series of common courses of crops, for gypsum. One was a light sand from Norfolk; another a clay, bearing good wheat, from Middlesex; the third a sand from Sussex; the fourth a clay from Essex. I found gypsum in all of them; and in the Middlesex soil it amounted nearly to one per cent. Lord Dundas informs me, that having tried gypsum without any benefit on two of his estates in Yorkshire, he was induced to have the soil examined for gypsum, according to the process described in the Fourth Lecture, and this substance was found in both the soils.—*Davy's El. Ag. Chym.* p. 303.

† *Gypsum* consists of sulphuric acid (the same body that exists combined with water in oil of vitriol) and lime; and when dry it is composed of fifty-five parts of lime and seventy-five parts of sulphuric acid. Common gypsum or selenite, contains, besides sulphuric acid and lime, a considera-

water, and assumes the form of a coherent mass by means of such mixture, still, by enclosing it in tight casks, it may be kept for several months without any sensible change of its properties.

Crude plaster, finely ground, is likewise extensively used; and many agriculturists consider it no less efficacious in this state, than that which has been burnt. I have tried both kinds; and though I could perceive that, during the first year, the burnt plaster had a little the best effect, there appeared to be no difference between the two in any of the three succeeding years.

Plaster is sown in a powdered state, with the hand, as soon as the leaves of plants begin to cover the ground; and this operation is commonly performed when the weather is somewhat damp and showery, it being thought best that the leaves should be moist, in order that they may retain a small portion of the plaster on their surface.

The effect of plaster is observable for three or four years; after which, in order to keep up a vigorous quantity of water; and its composition may be thus expressed:—

Sulphuric acid, one proportion	75
Lime, one proportion	55
Water, two proportions	34

The nature of gypsum is easily demonstrated: if oil of vitriol be added to quicklime, there is a violent heat produced; when the mixture is ignited, water is given off, and gypsum alone is the result, if the acid has been used in sufficient quantity; and gypsum mixed with quicklime, if the quantity has been deficient. Gypsum free from water is sometimes found in nature, when it is called anhydrous selenite. It is distinguished from common gypsum by giving off no water when heated.

Gypsum is soluble in about five hundred times its weight of cold water, and is more soluble in hot water; so that when water has been boiled in contact with gypsum, crystals of this substance are deposited as the water cools. Gypsum is easily distinguished when dissolved by its properties of affording precipitates to solutions of oxalates and barytic salts.—*Davy's El. Ag. Chym.* pp. 305, 306.

vegetation, its application must be renewed. The quantity ordinarily employed is not far from three hundred pounds to the acre.

There is much difference of opinion in relation to the manner in which plaster acts. Its fertilizing effects have been ascribed by some to the avidity with which it absorbs moisture. But there appears to be no sufficient foundation for this theory, since water becomes solidified by its combination with plaster; and this latter refuses to part with it, either to the air, by the action of atmospheric heat, or to any other surrounding body. Besides, were its operation as is here supposed, its effects would be merely momentary, and they would cease immediately after rain; which is by no means the case. And there is also this further consideration, that crude plaster has not the property of absorbing water, and is still attended with very nearly the same results as that which has been burnt. Though lime imbibes moisture even more eagerly than plaster, its effects are, notwithstanding, far less striking.

Another supposition is, that plaster acts only by promoting the putrefaction of animal substances, and the decomposition of manures. But to show that this opinion is no less unfounded than the former, Davy has incontestably proved, by direct experiment, that a mixture of plaster with manures, does not, in any degree, facilitate their decomposition.

There are those, again, who attribute the effects of plaster to its stimulating properties; and this I believe myself to be the only way of accounting for its fertilizing power.* Still it remains to be explained

* Very discordant notions have been formed as to the mode of operation of gypsum. It has been supposed by some persons to act by its power of attracting moisture from the air; but this agency must be comparatively insignificant. When combined with water, it retains that fluid too powerfully to yield it to the roots of the plant, and its adhesive attraction for moisture is inconsiderable; the small quantity in which it is used, likewise, is a circumstance hostile to this idea.

why this salt, being less stimulating than many others, should, nevertheless, produce such superior effects; why likewise its action should be prolonged for several years, while that of others is much less durable; and why, in fine, while the effect of the other salts, if applied in large quantities, is to burn up and entirely destroy plants, this, on the contrary, has no such tendency. These are problems in relation to the operation of plaster, which are as yet unexplained, nor can they be resolved, but by taking into consideration other circumstances besides merely its stimulating properties.

But with regard to the *effects* of plaster there is no such uncertainty; as agriculture, it is well known, has been abundantly enriched by its fortunate discovery. This fact of itself is sufficient for the farmer; and it is one, in common with many others, to which theory can impart no additional value.

I will, however, here briefly state what are my own views in relation to the action of plaster; and these I advance with the greater confidence, inasmuch as they appear to me to be deduced from analogies which admit not of being called in question.

It has been said that gypsum assists the putrefaction of animal substances, and the decomposition of manure. I have tried some experiments on this subject, which are contradictory to the notion. I mixed some minced veal with about one hundredth part of its weight of gypsum, and exposed some veal without gypsum under the same circumstances; there was no difference in the time in which they began to putrefy, and the process seemed to me most rapid in the case in which there was no gypsum present. I made other similar mixtures, employing in some cases larger and in some cases smaller quantities of gypsum; and I used pigeon's dung in one instance instead of flesh, and with precisely similar results. It certainly in no case increased the rapidity of putrefaction.

M. De Candolle thinks that gypsum is not so much useful in the soil, if indeed it is at all, as when scattered on the surface, and that it acts chiefly by stimulating the leaves of the plants to which it adheres.—(*Vide Physiologie Végétale*, p. 1273.)—*Davy's El. Ag. Chym.* pp. 306, 307, 309.

It is demonstrated that the salts most abundant in plants are those, the basis of which is lime or alkali. It is also proved by analysis, that these salts are present in variable proportions, in different species of plants, and even in different parts of the same plant.

On the other hand, we may see it evinced by daily observation, that saline substances, to be beneficial to plants, must be applied only in moderate quantities. Thus, if too large a proportion of salts, easily soluble in water, be mixed with the soil, the plants which grow in it will inevitably suffer, and finally die; nor will they fail to languish, if, on the other hand, they be altogether deprived of the stimulus afforded by salts. A small portion of marine salt, for example, either mixed with the manure, or spread by itself on the soil, gives increased action to the organs of plants, and encourages vegetation; while the same salt, if it be in excess, is always highly pernicious.*

* Common salt consists of the metal named sodium combined with chlorine; and pure soda consists of the same metal united to oxygen. When water is present which can afford oxygen to the sodium, soda may be obtained in several modes from salt.

The same reasoning will apply to the operation of the pure mineral alkali, or the carbonated alkali, as to that of the vegetable alkali; and when common salt acts as a manure, it is probably by entering into the composition of the plant in the same manner as gypsum, phosphate of lime, and the alkalis. Sir John Pringle has stated that salt in small quantities assists the decomposition of animal and vegetable matter. This circumstance may render it useful in certain soils. Common salt likewise is offensive to insects. That in small quantities it is sometimes a useful manure, I believe is fully proved; and it is probable that its efficacy depends upon many combined causes.

Some persons have argued against the employment of salt; because, when used in large quantities, it either does no good, or renders the ground steril; but this is a very unfair mode of reasoning. That salt in large quantities rendered land barren, was known long before any records of agricultural science existed. We read in the Scriptures, that Abimilech took the city of Sechem, "and beat down the city, and sowed

Since then the salts act upon plants, in proportion only as they are soluble in the water which is the vehicle of their conveyance, we may conclude that those which dissolve the least rapidly are the most beneficial to vegetation.

The water, by being unable to dissolve these saline substances, except very gradually, can convey to the plants only a small quantity of them at any one time; and, in this way, their effect will be constant and equable; nor will it cease, so long as the soil contains any portion of salts. Their action, again, will be prolonged, in proportion as the soil is more abundantly charged with them; nor will the plants at any time be liable to receive more than they really require.

Now plaster appears to possess precisely the degree of solubility which is here shown to be desirable; three hundred parts* of water being capable of dissolving one part only of plaster. Its action then must necessarily be constant and uniform, and without the

it with salt," that the soil might be for ever unfruitful. Virgil reprobates a salt soil; and Pliny, though he recommends giving salt to cattle, yet affirms that when strewed over land it renders it barren. But these are not arguments against a proper application of it. Refuse salt in Cornwall, which, however, likewise contains some of the oil and exuviae of fish, has long been known as an admirable manure. And the Cheshire farmers contend for the benefit of the peculiar produce of their country.

It is not unlikely that the same causes influence the effects of salt as those which act in modifying the operation of gypsum. Most lands in this island, particularly those near the sea, probably contain a sufficient quantity of salt for all the purposes of vegetation; and in such cases the supply of it to the soil will not only be useless, but may be injurious. In great storms the spray of the sea has been carried more than fifty miles from the shore; so that from this source salt must be often supplied to the soil. I have found salt in all the sandstone rocks that I have examined, and it must exist in the soil derived from these rocks. It is a constituent, likewise, of almost every kind of animal and vegetable matter.—*Davy's El. Ag. Chym.* pp. 312—314.

* Davy says five hundred parts.

possibility of its ever being so violent as to be hurtful. While the organs of plants, therefore, are gently stimulated by it, its effect is never to irritate or corrode them; whereas, in the case of the salts which are more easily soluble, the water becoming speedily saturated with them, they are conveyed by it in quantities altogether too abundant to the organs of plants, and consequently, by means of such excess, produce the most injurious results.*

* I made a number of experiments in May and June, 1807, on the effects of different saline substances on barley and on grass growing in the same garden, the soil of which was a light sand, of which one hundred parts were composed of sixty parts of siliceous sand, and twenty-four parts finely divided matter, consisting of seven parts carbonate of lime, twelve parts alumina and silica, less than one part saline matter, principally common salt, with a trace of gypsum and sulphate of magnesia: the remaining sixteen parts were vegetable matter.

The solutions of the saline substances were used twice a week, in the quantity of two ounces, on spots of grass and corn, sufficiently remote from each other to prevent any interference of results. The substances tried were *super-carbonate*, *sulphate*, *acetate*, *nitrate*, and *muriate of potassa*; *sulphate of soda*, *sulphate*, *nitrate*, *muriate*, and *carbonate of ammonia*. I found that in all cases when the quantity of the salt equalled one thirtieth part of the weight of the water, the effects were injurious; but least so in the instances of the carbonate, sulphate, and muriate of ammonia. When the quantities of the salts were one three hundredth part of the solution, the effects were different. The plants watered with the solutions of the sulphates grew just in the same manner as similar plants watered with rain water. Those acted on by the solution of nitre, acetate, and super-carbonate of potassa, and muriate of ammonia, grew rather better. Those treated with the solution of carbonate of ammonia grew most luxuriantly of all. This last result is what might be expected, for carbonate of ammonia consists of carbon, hydrogen, azote, and oxygen. There was, however, another result which I had not anticipated; the plants watered with solution of nitrate of ammonia did not grow better than those watered with rain-water. The solution reddened litmus paper; and probably the free acid exerted a prejudicial effect, and interfered with the result.

Few of the salts contribute anything to the actual nourishment of plants. They are principally useful in stimulating their organs, and thereby increasing their power of digestion. Animals, by possessing the faculty of locomotion, have no difficulty in providing themselves with such saline stimulants, and with whatever else may be required to impart a healthy and vigorous action to their digestive organs; and, having also the further advantage of will and instinct, they use these substances only in such proportions as their wants actually require. But plants, without any such power to help themselves, passively depend upon the air and water for all their necessary supplies; and this latter fluid carries to them, indiscriminately, whatever the earth contains that is capable of solution. It follows, therefore, from these premises, that the best saline manures are those which can only be very gradually dissolved.

Nor is this principle less applicable to manures generally, of whatever nature. There is this difference, however, between manures which are purely nutritive, and those of a saline and stimulating character. Where the former are too abundant, plants are surfeited with an over-supply of nutriment; they absorb more than they can properly digest, and acquire a sort of morbid obesity, which renders the texture of their organs lax, spongy, and soft, and thereby incapacitated for suitably maturing their products. When, on the other hand, stimulating manures are present in too great quantities, and, especially if they be easily soluble in water, the organs of plants speedily become surcharged with them, and are thus soon dried up and withered.

It appears, therefore, that the manures most favour-

Much of the discordance of the evidence relating to the efficacy of saline substances depends upon the circumstance of their having been used in different proportions, and in general in quantities much too large.—*Davy's El. Ag. Chym.* pp. 315, 316.

able to vegetation, are those, the solubility of which is such as to afford to plants a supply of nutriment neither too great nor too small, but always gradually and uniformly, and in proportion to their wants; and which is the case where manures, whether animal, vegetable, or saline, decompose slowly, so that a small quantity only of them is held in solution by the water at any one time.

Those animal substances which decompose the most slowly, and which in the progress of their decomposition are continually affording fresh soluble products, are the best of all manures; and of this we are furnished with abundant evidence in the highly fertilising power of bones, horns, and wool. What renders these substances so peculiarly valuable, is that they are at the same time alimentary and stimulating; containing, in addition to their nutritive properties, some particular salts, as ammonia, etc., the irritating action of which is constantly tempered by their combination either with carbonic acid, or with the animal matters themselves.

Turf or peat ashes,* and those also of pit coal, pro-

* Though it is not generally known, yet a series of experiments has been carried on for a great length of time in this country upon the operation of gypsum as a manure. The Berkshire and the Wiltshire peat-ashes contain a considerable portion of this substance. In the Newbury peat-ashes I have found from one fourth to one third of gypsum; and a larger quantity in some peat-ashes from the neighbourhood of Stockbridge: the other constituents of these ashes are calcareous, aluminous, and siliceous earth, with variable quantities of sulphate of potassa, a little common salt, and sometimes oxyde of iron. The red ashes contain most of this last substance.

These peat-ashes are used as a top-dressing for cultivated grasses, particularly sainfoin and clover. In examining the ashes of sainfoin, clover, and rye grass, I found that they afforded considerable quantities of gypsum; and this substance, probably, is intimately combined as a necessary part of their woody fibre. If this be allowed, it is easy to explain the reason why it operates in such small quantities; for the

duce surprising effects upon grass land. The first not unfrequently contain plaster; while at other times they are found to consist entirely of silica, alumina, and the oxyde of iron. I have, by analysis, obtained from the ashes of pit coal, sulphate of lime.

Wood ashes also, such as are produced from our domestic fires, are attended with very remarkable results. Their properties are far too stimulating before they are leached; but when they have been subjected to the action of water, and by this operation have become deprived of nearly all their salts, in which state they are known by the name of buck-ashes, they may still be used with very great effect; and especially on wet soils, and meadows. Not only do they promote the growth of the useful plants, but by their regular application for a succession of years, the soil may be entirely cleared of noxious weeds. In this way rushes may be destroyed on lands which are saturated with water, and their place supplied with clover and other plants of a useful character.

Where the soil is clayey and wet, the effect of wood ashes is not only to render it more light and dry, but to promote vegetation also by means of the stimulating salts which they contain.*

whole of a clover crop, or sainfoin crop, on an acre, according to my estimation, would afford by incineration only three or four bushels of gypsum.—*Davy's El. Ag. Chym.* pp. 307, 308.

* *Wood ashes* consist principally of the vegetable alkali united to carbonic acid; and as this alkali is found in almost all plants, it is not difficult to conceive that it may form an essential part of their organs. The general tendency of the alkalies is to give solubility to vegetable matters; and in this way they may render carbonaceous and other substances capable of being taken up by the tubes in the radicle fibres of plants. The vegetable alkali, likewise, has a strong attraction for water, and even in small quantities may tend to give a due degree of moisture to the soil, or to other manures; though this operation, from the small quantities used, or existing in the soil, can be only of a secondary kind.—*Davy's El. Ag. Chym.* p. 312.

CHAPTER V.

Of the Germination of Seeds.

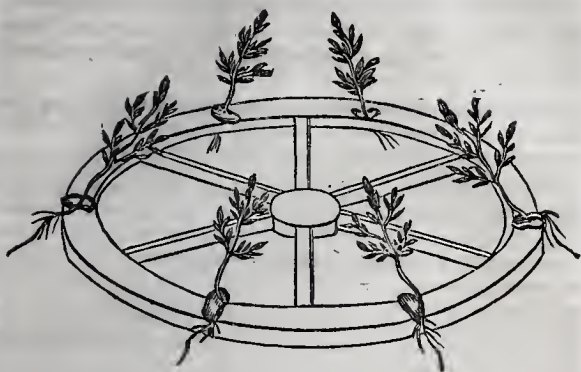
[FROM CHAPTAL'S CHYMISTRY APPLIED TO AGRICULTURE.]

It is by the united action of oxygen, heat, and moisture, almost exclusively, that the process of germination is carried on.*

* One of the most important properties belonging to matter is *gravitation*, or the power by which masses of matter are attracted toward each other. It is in consequence of gravitation that bodies thrown into the atmosphere fall to the surface of the earth, and that the different parts of the globe are preserved in their proper positions. Gravity is exerted in proportion to the quantity of matter. Hence all bodies placed above the surface of the earth fall to it in right lines, which, if produced, would pass through its centre; and a body falling near a high mountain is a little bent out of the perpendicular direction by the attraction of the mountain, as has been shown by the experiments of Dr. Maskelyne on Schehallien.

Gravitation has a very important influence on the growth of plants; and it is rendered probable, by the experiments of Mr. Knight, that they owe the peculiar direction of their roots and branches almost entirely to this force.

That gentleman fixed some seeds of the garden bean on the circumference of a wheel, which in one instance was placed vertically, and in the other horizontally, and made to revolve, by means of another wheel worked by water, in such a manner, that the number of the revolutions could be regulated; the beans were supplied with moisture, and were placed under circumstances favourable to germination. The beans all grew, notwithstanding the violence of revolution, which was sometimes as much as two hundred and fifty revolutions in a minute on the vertical wheel, which always revolved rapidly, and with little variation of velocity; the radicles, or roots, pointed precisely in the direction of radii in whatever direction they were first placed. The germes took precisely the opposite direction, and pointed to the centre of the wheel, where they soon met each other. Upon the horizontal wheel, the conflicting operation of gravitation and centrifugal force, occasioned the germes to form a cone, more or less obtuse, according to the velocity of the wheel, the radicles always



When pure water is absorbed by seeds, it increases their volume, and facilitates the development of their germes. The first of these effects is, however, purely

taking a course diametrically opposite to that taken by the germes, and, consequently, pointing as much below as the germes pointed above the plane of the wheel's motion.

These facts afford a rational solution of this curious problem, respecting which different philosophers have given such different opinions; some referring it to the nature of the sap, as De la Hire; others, as Darwin, to the living powers of the plant, and the stimulus of air upon the leaves, and of moisture upon the roots. The effect is now shown to be connected with mechanical causes; and there seems no other power in nature to which it can with propriety be referred, but gravity, which acts universally, and which must tend to dispose the parts to take a uniform direction.

Fig. 1 represents the case in which the horizontal wheel performed two hundred and fifty revolutions.

Fig. 2 represents the form of the experiment when the vertical wheel was made to perform one hundred and fifty revolutions in a minute.

If plants in general owe their perpendicular direction to gravity, it is evident that the number of plants upon a given part of the earth's circumference cannot be increased by making the surface irregular, as some persons have supposed. Nor can more stalks rise on a hill than on a spot equal to its base; for the slight effect of the attraction of the hill, would be only to make the plants deviate a very little from the perpendicular. Where horizontal layers are pushed forth, as in certain grasses, particularly such as the florin, lately brought into notice by Dr. Richardson, more food may, however, be produced upon an irregular surface; but the principle seems to apply strictly to corn-crops.

The direction of the radicles and germens is such, that both are supplied with food, and acted upon by those external agents which are necessary for their development and growth. The roots come in contact with the fluids in the ground; the leaves are exposed to light and air; and the same grand law which preserves the planets in their orbits is thus essential to the functions of vegetable life.

When two pieces of polished glass are pressed together they adhere to each other, and it requires some force to separate them. This is said to depend upon the *attraction of cohesion*. The same attraction gives the globular form to drops of water, and enables fluids to rise in capillary tubes;

physical, and it takes place no less in dead than in living seeds, as has been shown by M. de Saussure. It changes neither their taste nor odour, though, if they be dead, it disposes them to putrefaction; while a genuine and vital germination fails not successively to develop in them new properties.

There are seeds which will germinate under water, but then it is only where that fluid contains a great quantity of air; and if there be but little of this latter present, the volume of water must be proportionably increased, to obtain the same result. Germination

and hence it is sometimes called *capillary attraction*. This attraction, like gravitation, seems common to all matter, and may be a modification of the same general force; like gravitation, it is of great importance in vegetation. It preserves the forms of aggregation of the parts of plants, and it seems to be a principal cause of the absorption of fluids by their roots.

If some pure magnesia, the calcined magnesia of druggists, be thrown into distilled vinegar, it gradually dissolves. This is said to be owing to *chymical attraction*, the power by which different species of matter tend to unite into one compound. Various kinds of matter unite with different degrees of force: thus sulphuric acid and magnesia unite with more readiness than distilled vinegar and magnesia; and if sulphuric acid be poured into a mixture of vinegar and magnesia, in which the acid properties of the vinegar have been destroyed by the magnesia, the vinegar will be set free, and the sulphuric acid will take its place. This chymical attraction is likewise called *chymical affinity*. It is active in most of the phenomena of vegetation. The sap consists of a number of ingredients, dissolved in water by chymical attraction; and it appears to be in consequence of the operation of this power, that certain principles derived from the sap are united to the vegetable organs. By the laws of chymical attraction, different products of vegetation are changed, and assume new forms: the food of plants is prepared in the soil; vegetable and animal remains are changed by the action of air and water, and made fluid or aëriform; rocks are broken down and converted into soils; and soils are more finely divided and fitted as receptacles for the roots of plants.—*Davy's El. Ag. Chym.* pp. 30—34.

will not take place at all in water which is entirely destitute of air.

As seeds begin to germinate, they absorb oxygen, and envelope themselves in an atmosphere of carbonic acid. This they are enabled to do, however, only by being in contact either with the atmospheric air, or with water highly charged with that fluid. If, while they are fresh and succulent, they be secluded from air and moisture, they will rot; but when dry, under the same circumstances they experience no change, and retain their germinating power, until, by exposure to air and moisture, it is brought into a condition to develop itself.

Germination is rapid in proportion to the quantity of oxygen existing in the air; and large seeds absorb this gas more abundantly than small.*

* Seeds are incapable of germinating, except when oxygen is present. In the exhausted receiver of the air-pump, in pure azote, in pure carbonic acid, when moistened they swell, but do not vegetate; and if kept in these gases, lose their living powers, and undergo putrefaction.

The absorption of oxygen by the seed in germination, has been compared to its absorption in producing the evolution of fœtal life in the egg; but this analogy is only remote. All animals, from the most to the least perfect classes, require a supply of oxygen.

The impregnated eggs of insects, and even of fishes, do not produce young ones, unless they are supplied with air, that is, unless the fœtus can respire. I have found that the eggs of moths did not produce larvæ when confined in pure carbonic acid; and when they were exposed in common air, the oxygen partly disappeared, and carbonic acid was formed. The fish in the egg or spawn gains its oxygen from the air dissolved in water; and those fishes that spawn in spring and summer in still water, such as the pike, carp, perch, and bream, deposit their eggs upon subaquatic vegetables, the leaves of which, in performing their healthy functions, supply oxygen to the water. The fish that spawn in winter, such as the salmon and trout, seek spots where there is a constant supply of fresh water, as near the sources of streams as possible, and in the most rapid currents, where all stagnation is prevented, and where the water is saturated with air, to which

In the process of germination seeds give out carbonic acid only; and the oxygen which they consume is always equal in volume to that of the carbonic acid which they exhale.* For these facts we are indebted to the admirable experiments of M. de Saussure.

It would appear, therefore, that oxygen is the sole agent in germination; while carbonic acid is its only product. The seed is made to part with a portion of carbon, and beyond this there is no combination of the oxygen with any of its principles; for if seed be made to germinate in a volume of one hundred cubic inches of air, of which twenty-one parts are oxygen, it will be

it has been exposed during its deposition from clouds. It is the instinct leading these fish to seek a supply of air for their eggs which carries them from seas or lakes into the mountain country, which induces them to move against the stream, and to endeavour to overleap weirs, mill-dams, and cataracts.

It is evident, that in all cases of tillage the seeds should be sown so as to be fully exposed to the influence of the air. And one cause of the unproductiveness of cold clayey adhesive soils is, that the seed is coated with matter impermeable to air.

In sandy soils the earth is always sufficiently penetrable by the atmosphere; but in clayey soils there can scarcely be too great a mechanical division of parts in the process of tillage. Any seed not fully supplied with air, always produces a weak and diseased plant.—*Davy's El. Ag. Chym.*, pp. 202—204.

* Some persons have supposed that plants exposed in the free atmosphere to the vicissitudes of sunshine and shade, light and darkness, consume more oxygen than they produce, and that their permanent agency upon air is similar to that of animals. But all experiments brought forward in favour of this idea, have been made under circumstances unfavourable to accuracy of result. The plants have been confined and supplied with food in an unnatural manner; and the influence of light upon them has been very much diminished by the nature of the media through which it passed. Plants confined in limited portions of atmospheric air soon become diseased; their leaves decay, and by their decomposition they rapidly destroy the oxygen of the air.—*Davy's El. Ag. Chym.*, p. 211.

found, supposing the germination to have produced fourteen cubic inches of carbonic acid, that seven inches of free oxygen will remain. It is hence evident that, in this incipient stage of vegetation, water imparts no one principle to the seed, neither is it itself decomposed; but it must not from this be inferred that water is without use in the germination of seeds; for it is well known that if they be in an entirely dry state, they will not germinate at all though in contact with the air.

I consider that water has these two undeniable uses in the process of germination; first, to penetrate the substance of the seed, and to introduce the oxygen of the air which it holds in solution, thereby occasioning the first disengagement of carbon; and secondly, by softening and dilating it, to render it accessible to the atmospheric air, so that this latter may freely enter in, and produce the effects which have been already described.

It follows, therefore, from these premises, that there can be no proper germination of seeds, unless they be in contact with the atmospheric air; and consequently, that, if they be buried too deep, or, from its compact nature, the air be unable to penetrate the soil, this process cannot be carried on; and farther, that wherever water, in a stagnant state, remains for a long time on the surface of the earth, the seed in such case instead of germinating, will rot; and that when the earth is perfectly dry, seed will not germinate in it at all, except it be moistened.

The circumstance that seeds do not germinate when they are too deeply covered, explains to us why after deep tilling, we sometimes observe plants springing up, precisely of the same kind as were cultivated on the soil years before; and the different states of the earth with respect to dryness, at the time of sowing, furnishes us also with a reason, why, independent of the action of heat, seeds are more or less quick in sprouting.

Germination will not take place in pure carbonic acid gas; and even when this is mixed with the atmospheric air, it retards the operation; so that seeds may be made to germinate more rapidly, if the carbonic acid which they give out be absorbed by means of lime or the alkalies.*

In its feeble incipient state of vegetation, the seed rejects those aliments, which afterward, as the young plant advances in strength, become the principal agents in its nutrition.

Seeds germinate in the same time, whether in light or in darkness; but it has been observed by M. de Saussure, that the subsequent development of the plant is both more perfect and more rapid, in the former case than in the latter.

As it respects the germination of seeds, then, all that is known appears to be embraced in the following facts:—

Water or moisture penetrates and swells the seed, and the oxygen which it holds in solution operates to deprive it, for the first time, of a portion of the carbon which is its principal constituent.

When seeds are thus expanded, their substance becomes accessible to the atmospheric air, and the oxygen of this combining freely with the carbon, disengages it in the form of gas.

The heat essential to germination facilitates the action of the oxygen, and the volatilization of the carbonic acid; while, at the same time, it stimulates the germe, and hastens its development.

By the subtraction of a portion of their carbon, the nature and properties of seeds become essentially changed. The mucilage and starch of which they are

* Some few plants will germinate in an artificial atmosphere, consisting principally of carbonic acid; and many will grow for some time in air containing from one half to one third; but they are not so healthy, as when supplied with smaller quantities of this elastic substance.—*Davy's El. Ag. Chym.*

almost exclusively composed, by being deprived of a part of their carbon, are converted into a soft, milky, saccharine substance, and this affords the first nutriment to the embryo plant.

CHAPTER VI.

On the Nutrition of Plants.

[FROM CHAPTAL'S CHYMISTRY APPLIED TO AGRICULTURE.]

THE moment that plants begin to unfold their first leaves, and to fix their roots in the earth, they seek from the atmosphere and the soil on which they grow, for new aliments.

The leaves and roots are the principal organs for furnishing to plants their necessary food. The first absorb certain of the gases contained in the atmosphere, while the latter imbibe from the soil its salts and juices along with the water in which they are conveyed; and likewise the gases developed in the earth, and which are introduced either by the air, or by the water which holds them in solution.

ARTICLE I.

On the Influence of Carbonic Acid upon Nutrition.

Plants absorb from the air and water the carbonic acid which they contain. This they decompose in the daytime, and assimilate, and appropriate for their nourishment the carbon and a part of the oxygen.

A small addition of carbonic acid to that which is contained naturally in the atmosphere, assists vegetation; while too large a quantity of it is injurious.

This gas is indispensable to vegetation; though plants do not require it equally in all stages of their growth. When a plant is very young, and has just

begun to develop its leaves and roots, it will suffer, and become drooping, if water impregnated with carbonic acid be applied to it; whereas, at a more advanced period of its growth, it will be made to vegetate with greater luxuriance by a similar application.

According to the observations of Sennebier, young leaves decompose from an equal volume of air, less carbonic acid gas in the same time, than those which are full grown.

Generally speaking, vegetation is accelerated by mixing with atmospheric air one tenth or even one twelfth of its volume of carbonic acid gas, but it is only where plants are exposed to the sun, that this favourable effect will be experienced.* If they be growing in the shade, any addition whatever of this gas will prove injurious.

The effects of vegetable mould, and of various other substances, in promoting vegetation, is in a great measure attributable to the carbonic acid which they are constantly giving out to the atmosphere, or transmitting immediately to the plants.

It is the particular office of the leaves to absorb

* When a growing plant, the roots of which are supplied with proper nourishment, is exposed in the presence of solar light to a given quantity of atmospherical air, containing its due proportion of carbonic acid, the carbonic acid after a certain time is destroyed, and a certain quantity of oxygen is found in its place. If new quantities of carbonic acid gas be supplied, the same result occurs; so that carbon is added to plants from the air by the process of vegetation in sunshine; and oxygen is added to the atmosphere.

This circumstance is proved by a number of experiments made by Drs. Priestley, Ingenhousz, and Woodhouse, and M. T. De Saussure; many of which I have repeated with similar results. The absorption of carbonic acid gas and the production of oxygen are performed by the leaf; and leaves recently separated from the tree effect the change, when confined in portions of air containing carbonic acid; and absorb carbonic acid and produce oxygen, even when immersed in water holding carbonic acid in solution.—*Davy's El. Ag. Chym.* p. 209.

and to decompose carbonic acid, the carbon of which they retain, and appropriate to the uses of the plant. This decomposition is carried on with great activity while they are exposed to the sun; and they give out in the meantime to the atmosphere most of their oxygen, and a small portion of nitrogen mingled with it.

According to the experiments of M. de Saussure, plants, in decomposing carbonic acid gas, appropriate for nutriment a trifling proportion of its oxygen, while they throw off the remainder into the air.

The activity with which this process is carried on is proportioned to the intensity of the solar light, and the healthiness and verdure of the leaves. It would appear, however, that even where plants are secluded from the light, this decomposition may be carried on, though not very rapidly; since Sennebier has taken notice that leaves, when unfolded in this situation, were perceptibly tinged with green, which he attributes to the decomposition of carbonic acid.

I will here relate what I noticed many years ago, at the coal mines of Bousquet in the arrondissement of Beziers.

The pieces of timber which support the roof of the long gallery leading to the coal beds, were covered with the kind of toadstools, which ordinarily attach themselves to the trunks of old trees. The entrance of this gallery has abundance of light; but as you advance it becomes imperceptibly fainter, till at last you are involved in total darkness. I was struck with the varied aspect of the fungi at different depths along this gallery; those at the entrance were of a yellow colour, and their texture so firm that it was with difficulty they could be broken with the hand. As I proceeded, their reddish yellow colour became more and more faint, and their substance more loose and spongy; until at the extremity of the gallery, where no light ever penetrates, they were entirely white, and almost wholly without consistence; so that in pressing them with the hand, they gave out scarcely

anything but a liquid substance, and a very small portion of fibrous matter, though they were as large as any of the rest. I filled several bottles with these last, and brought away with me in my hand a few of those which grew in the centre and at the entrance of the gallery. A comparative analysis of these different plants produced, for those at the extremity of the gallery, merely water saturated with carbonic acid, a small portion of mucilage, and a little spongy fibre floating on the liquid; while in such as were taken from the less interior parts, and especially in those from the entrance of the gallery, I found a much smaller proportion of acid, and a far greater quantity of ligneous matter.

It would appear, therefore, that the fungi at the extremity of the gallery contained merely the elements of nutrition in an unelaborated state; while in the others the process of assimilation had been carried on more or less perfectly, in proportion as vegetation had been aided by the access of light, and of the atmospheric air. And as carbonic acid was more abundant in the more remote parts of the gallery than at the entrance, it was to be expected that the plants which grew there should be more abundantly impregnated with it.

ARTICLE II.

Agency of Oxygen Gas in Vegetation.

Leaves in a healthy state absorb oxygen gas during the night; but the phenomena attending this process are different in different plants.

The leaves of the oak, of the horse-chestnut, of the false acacia, &c., absorb oxygen; and, at the same time, the volume of carbonic acid disengaged is less than that of the oxygen consumed. Those of pulpy plants, if they be confined with a given quantity of air, diminish its volume, without any sensible production of carbonic acid.

The quantity of oxygen which plants absorb is proportioned to their vigour; and it depends likewise upon temperature, being greater, for example, at 88° Fahrenheit, than at 55° or 66° .

If plants be kept for several successive nights under a receiver filled with atmospheric air, their leaves will continue to absorb oxygen, but not so rapidly; and they are saturated with it, when they contain one and a fourth of their own volume.

As soon as leaves become saturated with oxygen gas, they form carbonic acid by combining their carbon with the oxygen of the air, without, however, changing its volume; and, in the production of this acid, they never employ more than half the oxygen which they are capable of absorbing.

The oxygen which is absorbed by leaves is found to be in a state of combination with them. By placing them in a vacuum and applying heat, only one sixteenth of the volume of gas absorbed by them can be disengaged: and even this will not be pure oxygen, but a mixture of nitrogen gas, carbonic acid, and oxygen.

It is most probable that the oxygen gas which plants absorb during the night, enters into combination with their carbon, to form carbonic acid: which latter remains in a state of solution in their juices, until by the return of the sun it becomes decomposed; when through the transpiration of the leaves the oxygen is given off to the atmosphere, while the carbon is retained and enters into the composition of the plant.

Plants will not grow except in air which contains oxygen; still in the shade they do not thrive as well in pure oxygen gas, as when it is mixed with other gases, such as carbonic acid and nitrogen.

The leaves of different plants consume in the shade, unequal quantities of oxygen gas. Those of pulposus plants absorb but little oxygen; but then they retain it more pertinaciously than others, and give out less

carbonic acid. Since plants of this description are thus retentive of their carbon, and imbibe, at the same time, but little oxygen, they will live in the most steril soils, and are found growing not only upon dry and naked sands, but at elevations where the air is greatly rarified.

The leaves of deciduous trees, generally, absorb the most oxygen, and contain the greatest quantity of carbon. These plants not only prepare all the juices which are required for their vegetation and the formation of their fruits, but, even after they have fulfilled these offices, they still continue to draw from the air and earth the elements of their nourishment. These elements they elaborate and deposite in the cells of the alburnum, to serve for nutriment on the first return of spring, and until, by the development of their leaves, and through the stimulus of heat acting upon their roots, the organs of these are enabled to provide nutriment by the absorption of external substances. For these facts we are indebted to the experiments of Mr. Knight.

The phenomenon in vegetation here noticed, is very similar to what we observe in most of the insect tribes, in some species of birds, and in different kinds of quadrupeds, which become torpid during the winter, and, while in this condition, are supported by the fat which has been stored up in their celular membrane the preceding autumn.

Plants growing in wet places, as in marshes, and therefore almost constantly exposed to a damp atmosphere, consume less oxygen gas than most others of an herbaceous kind, which are differently situated.

The quantity of oxygen which plants absorb is, generally, greater in proportion as the soil in which they grow is more fertile, and as the surrounding atmosphere is more abundantly supplied with this principle. These facts are deduced from numerous experiments made by M. de Saussure.

Roots, in a healthy condition, if they be separated

from their stems and placed under a bell-glass, will diminish the volume of atmospheric air, and form carbonic acid from the contiguous oxygen gas; in which case they never absorb a quantity of this gas of greater volume than their own. If these roots, after being thus saturated with oxygen, be placed under another receiver, they will form carbonic acid without changing the volume of the air; and if, again, they be exposed for a short time to the open air, they will absorb a quantity of oxygen gas nearly equal to their own volume, as when enclosed under the receiver in the first instance; which proves that free atmospheric air has the power to deprive them of the carbonic acid which they form.

Roots then, it is evident, perform the same office as leaves in relation to oxygen; but they absorb a less quantity of it. They differ also in this—that they do not decompose carbonic acid gas, which operation appears to be exclusively confined to the leaves, to which the acid is carried that it may be there decomposed by the action of the solar rays.

Results different from the above take place, when the roots are not separated from the stem. They will then absorb several times their own volume of oxygen gas; the reason of which is obvious. The carbonic acid formed in this case being immediately dissolved in the juices of the roots, passes at once into the stalk of the plant, and from this into the leaves, in the organs of which its decomposition is chiefly performed; so that the roots, instead of retaining the carbonic acid, are relieved of it as fast as it is produced; and are at no time surcharged with this acid, notwithstanding it is constantly being formed.

The roots not only absorb oxygen gas from the atmospheric air which penetrates the soil, and is brought in contact with them, but there being a portion of this gas always present in the water by which they are moistened, this they likewise disengage.

This reminds me of a fact which I have frequently

noticed, and which I shall here attempt to explain. It is the case with most kinds of trees, if the soil in which they grow be submerged in stagnant water, so that their roots can no longer come in contact with the atmospheric air, that they speedily languish, their leaves turn yellow, and the trees themselves soon die. The reason of this appears to be, that the water becoming exhausted of oxygen gas, and at the same time receiving no new supplies, the roots are thus cut off from all means of providing themselves with this indispensable principle, and consequently they decay and die; whereas, the results are altogether different, when, on the other hand, the roots are washed with running water; since this is at all times abundantly charged with oxygen gas, and the roots are constantly absorbing it for the formation of carbonic acid, which constitutes the nutritive principle of plants.

Neither the wood, the parenchyma, the petals, nor, generally, any other than the green parts of plants, alternately imbibe and exhale oxygen gas during the night; but then they absorb it in small quantities, and this combining with their carbon remains in a state of solution in their juices, until at length it is conveyed to their leaves, there to be decomposed by the action of solar light and heat. It would appear, therefore, that carbon, which is one of the elements most abundant in the juices, and in all manures which contribute to the nourishment of plants, must first be combined with oxygen in order to form carbonic acid, before it can be assimilated by them. In this state it is thrown off into the atmosphere, from which it is again gradually absorbed by the leaves, and decomposed by their action. And what seems to confirm the opinion here advanced, is the fact, that if by means of lime or the caustic alkalies the carbonic acid be absorbed as fast as it is transpired by the leaves, the plants invariably die.

ARTICLE III.

On the influence of the Air upon Fruits.

Berard in experimenting on this subject, placed different kinds of green fruit, some in bottles which he afterward tightly corked, and others under bell-glasses, which he inverted over mercury, and then exposed them to a strong light. At the expiration of twenty-four hours he analyzed the air contained in these different vessels, which was in volume from seven to eight times more than the fruit, and found it uniformly to yield the following results:—

Carbonic acid		4
Oxygen		16.8
Nitrogen		79.2
		100

A part of the oxygen had, in every instance, disappeared; and in place of it there was nearly an equal volume of carbonic acid. The quantity of this latter is often found in such experiments to be somewhat less than that of the oxygen which has been absorbed. By diminishing the volume of air, nearly the whole of the oxygen may be absorbed. From experiments made with vessels, in which the fruits occupied a space equal to one third of their capacity, the following products were obtained:—

Carbonic acid		18.52
Oxygen		1.96
Nitrogen		79.52
		100

It would appear, therefore, to be demonstrated by these experiments, that fruits exposed to the action of air, in a strong light, and under the successive influences of day and night, uniformly absorb oxygen; and that this principle combining with their carbon,

forms a volume of carbonic acid nearly equal to that of the oxygen which they have absorbed.

The same results take place when the vessels are exposed to the direct rays of the sun; with this difference, however, that the air contained in them is then more rapidly and more perfectly decomposed, than is the case in the daylight merely, or during the night.

A bell-glass containing almonds having been exposed to the sun from nine o'clock in the morning to four in the afternoon, the constituent principles of the air in it were found to be as follows:—

Carbonic acid		15.74
Oxygen		5.65
Nitrogen		78.61

100

In this experiment, besides the carbonic acid which was formed by the oxygen of the air combining with the carbon of the fruit, it would appear that the fruit itself must also have furnished a small quantity; from which circumstance it was concluded by Berard, that, fruits act upon atmospheric air in a manner widely different from leaves. Instead of changing the carbonic acid of the air into carbon and oxygen, as is the case with leaves when exposed to the solar rays, fruits combine the oxygen with their own carbon, to form carbonic acid; and consequently, whether they be in the sun or shade, they absorb oxygen and transpire carbonic acid.

Berard found the results to be precisely the same, in experimenting upon fruits still attached to the tree, and in a state of vigorous vegetation. He therefore inferred from the foregoing premises, that the ripening process of fruits was carried on through the subtraction of their carbon by the oxygen of the surrounding air. Whenever by any means this subtraction of carbon is stopped, the fruit invariably withers and dies.

If a vacuum be formed in the receivers containing the fruit, or if it be enveloped in an atmosphere of hydrogen, nitrogen, or carbonic acid gas, it will, in this case, immediately commence giving out a small quantity of carbonic acid; but this will soon sensibly diminish, and toward the third or fourth day cease altogether.

In these experiments fruits will remain for a long time without undergoing any change; they continue perfectly stationary, and make not the least progress in ripening; but when, at the expiration of several days, they are again placed in a situation to absorb oxygen and transpire carbonic acid, they go on maturing as before.*

After they are ripe, fruits still continue to absorb oxygen, combining it with a portion of their carbon, to form carbonic acid; besides which they afford of themselves abundance of this acid, derived from the combination of their own elements.

Berard, in analysing several kinds of fruits in different states of maturity, found that they all contained the same principles, but in unequal proportions. The following were the results of one of these comparative analyses.

	Apricots very green.	Apricots more advanced.	Apricots Ripe.
Animal matter,	0.76	0.34	0.17
Green colouring matter,	0.04	0.03	0.10
Woody fibre,	3.61	2.53	1.86
Gum, ...	4.10	4.47	5.12
Sugar, some indications of		8.64	16.48
Malic acid, . . .	2.10	2.30	1.80
Lime, a very small quantity		"	"
Water, ...	89.39	84.49	74.87

* Unripe peaches, plums, and apricots, may be preserved in close bottles, filled with air deprived of oxygen, for from twenty days to a month; and pears and apples about three months, when they will afterward ripen perfectly by exposure to air.—*Davy's El. Ag. Chym.* p. 218.

Cherries, currants, plums, peaches, &c. analysed in a green and ripe state, afforded the same results, with some trifling difference only in the proportions of their products.

As fruits ripen, the animal matter, the woody fibre, the malic acid and the water become less, while the sugar is considerably increased. This last product, obtained from the grape, the fig, and the peach, when entirely ripe, may be partially crystallized; while that from apples, pears, currants, cherries, apricots, and plums cannot be made to assume this form, but continues permanently in a liquid state.

Green fruits will not ripen, if they be placed in an atmosphere deprived of oxygen; the maturing process is, however, in this case, only suspended, and will go on again as soon as the fruit is restored to a condition in which it can obtain this principle; provided, nevertheless, that it has not remained too long in the un-oxygenated air.

After being matured, fruits undergo still another change, which produces a most essential alteration in their nature; they become soft and mellow, or they decay, and give out in this state a great quantity of carbonic acid. The carbon in this case is furnished principally by the ligneous matter, which becomes of a dark colour, and by the sugar, which is thus gradually diminished until it at length wholly disappears; while the oxygen it must be supposed is furnished by the decomposition of the water. And I am the more confirmed in this opinion by the fact, familiar to every one, that when fruits in a large mass begin to decay, they give out to the surrounding atmosphere a peculiar odour, not unlike what is produced by certain gaseous combinations, and those especially of hydrogen with carbon.

De Saussure, after performing the same experiments upon fruits, arrives at conclusions somewhat different from those of Berard; and he thinks that this may be attributed to the circumstance, that the lat-

ter enclosed his fruits in bottles only large enough to contain six or eight times their volume of air; and that the sides of these vessels, by being so near each other, became heated by the sun, and thus produced a change in the fruits, approaching to incipient decomposition.

It may be inferred from the experiments of de Saussure, that green fruits act upon the air the same as leaves, though less powerfully. Fruits, like leaves, absorb oxygen from the atmosphere during the night, and supply its place with the carbonic acid which they throw off, a portion of which they likewise absorb.

Fruits give out oxygen when exposed to the sun; and they consume more oxygen in the dark when in a green state, than when they are approaching to maturity.

In all his experiments, de Saussure employed a volume of air from thirty to forty times greater than that of the fruit; by which means the heating action of the sun was greatly diminished, and thus prevented from affecting injuriously the results.

The experiments of Berard furnish results, all of which are referable to the maturing process in fruits, and it was with this subject particularly that he was occupied; while those of de Saussure relate especially to their vegetation and growth. The first has directed his observations to the changes which they undergo when detached from the tree; and if he has sometimes employed green fruits in his experiments, by being placed in small receivers, their action was rendered nearly the same, as though they had been dead. The second was, on the other hand, engaged in analyzing the phenomena of their vegetation; and with this explanation, it will appear in nowise strange that they should have differed in their results.

ARTICLE IV.

On the Influence of Water upon the Nutrition of Plants.

Water acts upon vegetation not only by supplying to plants the nutritive principles digested by them and appropriated as food, but by means also that are purely physical, as we shall now proceed to explain.

The effect of water, in the first place, is to moisten and divide the soil, and thereby to render its condition favourable to the extension of roots, the introduction of air, and the germination of seeds.

Another important operation of water consists in its conveying the oxygen, which is always more or less abundantly in a state of solution with it, to seeds; this being the first nutritive principle which they require, and, as we have already remarked, the chief agent in their germination.

And lastly, its effect is to separate the particles of manures, and to dissolve certain of their principles, and convey them directly to the organs of plants, so that they may be elaborated by their organs and converted into nutriment.

All sorts of water, however, are not equally favourable for these purposes. Rain-water, in consequence of its being the purest, and the most abundantly charged with air, is the best; and no other kind will make its place good.

Generally speaking, waters which flow from granitic and primitive calcareous regions, are highly propitious to vegetation; provided, however, that they do not pass over soils which impart to them metallic salts and earths, and that the length of their course is such, before being used for irrigation, that they will have become impregnated sufficiently with atmospheric air.

Though water be impure, it may, nevertheless, be usefully employed in irrigation; especially when,

either in a state of simple mixture or of solution, it conveys with it such salts, or such animal or vegetable substances, as are favourable to vegetation. In this case it acts with a twofold power, and with greatly increased effect.

Water, in relation to its uses in vegetation, may be divided into three kinds; first, that which contains animal substances; secondly, that which holds in solution certain vegetable elements; and thirdly, pure water, or such as is very slightly impregnated with salts.

The kind of water first mentioned is the most active; and especially if it contain the grease of wool, or the ammoniacal combinations which are formed by the fermentation of ground bones, horn-shavings, or the waste of wool. When these substances are employed as manures in a dry state, their effect is very gradual; but in a state of decomposition from putrefaction, and, when as fast as they are developed, the water seizes on all their products, and conveys them to the organs of the plants, their action becomes greatly more powerful. Liquid animal substances, and those of a soft and fleshy nature, are less permanent in their effects; and for the reason that, owing to the rapidity of their decomposition, they can continue to act only for a comparatively short time.

The second kind of water here alluded to, in consequence of its containing certain vegetable products, either natural, or such as have been derived from decomposition, forms an excellent manure. After plants by the action of water have become exhausted of all the principles which this liquid can dissolve, the gradually progressive decomposition of their insoluble fibre still continues to afford soluble products, which serve as nutriment to plants; being conveyed to their organs by the water with which they become combined as soon as they are formed. It is thus that dead plants furnish aliment to the living; the same elements

being found common to both, though differently combined.

When either the natural products of plants, or those which are derived from their decomposition are steeped, or dissolved in urine, or any of the animal fluids impregnated with salts, their action upon vegetation becomes much more powerful; since the effect of the salts is to stimulate the digestive organs, and, at the same time, to dissolve the juices, which, without this, would be in a state wholly unfitted to be absorbed by these organs. We hence perceive the reason why rapeseed cakes, and those of colesseed or of nuts, when treated in a similar manner, form the most powerful of all manures.

The kind of water last to be considered is that which contains salts in a state of solution. The different salts perform various offices in the process of vegetation. There are some which serve merely to stimulate the vital functions of plants, and to increase their activity; and the effect of which upon plants is not unlike that of the spices, of marine salt, saltpetre, etc. upon the human body. These salts applied to the soil, whether by themselves, or mixed with manure, never fail of producing an excellent effect.

But that the salts may be serviceable to vegetation, care must be taken not to employ them in too large quantities, as by such means their action is rendered so violent as to wither and dry up the plants. Thus it is that lands which have been for a long time submerged in sea-water, are wholly unfit for any kind of culture, until, by the continued washing of fresh water, they are at length deprived of the salt with which such lands are so abundantly impregnated.

There are salts, again, which, passing with the water into the substance of plants, become there decomposed; in consequence of which, in addition to their stimulating action, they contribute, by the assimilation of their elements, to the nourishment of the plant. Most of the salts, the constituent principles

of which belong either to the animal or vegetable kingdom, are of this character.

We have thus far considered water only in relation to its mechanical agency. It now remains to explain its more direct influence upon plants.

It has been shown by the experiments of de Saussure that plants, in decomposing water, appropriate the oxygen and hydrogen to themselves. But this assimilation would be of little use to them, unless they could, at the same time, absorb carbonic acid; the truth of which is abundantly evinced by the little increase of weight which plants acquire, when in an atmosphere consisting purely of oxygen.

Dead plants in a state of decomposition, without being in free contact with oxygen, form carbonic acid gas; which is produced, however, by their carbon combining with the oxygen which is always contained in vegetable products.

It appears to be chiefly by the decomposition of water, that plants are supplied with hydrogen; and this, next to carbon, would seem to be the principle in which they most abound. Hydrogen may be obtained from plants by means of distillation. During the spontaneous decomposition of dead vegetables it combines either with oxygen, again to form water, or with carbon, to be exhaled in the form of carburetted hydrogen.

ARTICLE V.

The Nutrition of Plants continued.

It would seem to be clearly shown, that the only principles which plants acquire from water and the atmospheric gases, are carbon, oxygen, and hydrogen. It is by analysis, however, fully proved, that, in addition to these principles, and the products resulting from their combinations, they contain, also, nitrogen and different earthy and saline matters, which could be derived from neither of the abovenamed elements.

It remains, therefore, to be considered in what manner these lastmentioned substances are introduced into their organs.

The nitrogen, which is found in the albumen, the gelatine, and the green colouring matter of plants, is not, at least to any perceptible extent, extracted by them from the atmosphere, notwithstanding that it constitutes four fifths of that fluid; but it is conveyed by water into their organs, along with the oxygen with which it is combined.

The earths which are insoluble in water, and which merely mix with or become suspended in that liquid, are not absorbed, except in very small quantities, by the organs of plants. They may, however, by means of certain chymical agents, such as the acids, the alkalies, etc., be introduced into these organs. As to the inconsiderable quantity of such earths ordinarily present in plants, we shall readily perceive that their introduction must be greatly facilitated by their being in a state of extremely minute division in water; this fluid, at the same time, serving as the vehicle of their conveyance.

There are plants which grow upon the naked rock, and which are enabled to obtain from the surrounding atmosphere, and from the water which falls in rain, the little nutriment which they require; of this description are the mosses, the ferns, and certain pulpous or fleshy plants. The growth of these plants is slow, their transpiration scarcely anything, and their colour continues the same nearly the whole year round; so that they must be constantly absorbing carbonic acid and water, and assimilating their elements. The few saline and earthy principles which they contain, are derived from portions of these substances brought by the wind and deposited upon their leaves; whence, in a state of solution with the water which falls upon them, they are introduced along with it into the organs of the plants.

It is the nature of plants, in a greater or less degree,

to exhaust the soil in which they grow; an effect which is produced to a far greater extent by annual than by perennial plants. These first are unable to obtain from the air and from water alone, an adequate supply of nutriment; for if they be placed in pure sand moistened only with distilled water, although they may be made to flower, they never, under these circumstances, thoroughly mature their seed; as has satisfactorily been shown by the experiments of Giobert, Hassenfratz, de Saussure, and others.

Plants of this description which transpire the most abundantly, are those which most exhaust the soil. Peas, beans, and buckwheat, notwithstanding they have succulent stems and leaves, as they transpire but little, are proportionably less exhausting in their action.

When, however, annual plants are cut at the time they are in flower, they do not impoverish the soil; since their roots being of a succulent nature, return to it in the manure they form, an amount of vegetable nutriment equal to that of which it has been deprived by the process of vegetation. But when this operation is performed after plants have matured their fruits, their roots being then dry, furnish comparatively but a very small quantity of fertilising materials to the soil.

During the time they are forming their fruits, plants not only draw from the soil the nutritive principles which it contains, but they likewise convert to their use in the process of maturation, the nutritive juices already existing in their stems and roots; so that these latter become gradually exhausted of their moisture, until at length they are reduced to mere woody fibre. It is from ignorance of this principle, that farmers are almost always too late in mowing their meadows, both natural and artificial. The time most suitable for this operation is when the grass is in flower; since by postponing it beyond that period, and until the seed is formed, two very serious disadvantages are incurred.

In the first place, the fodder obtained is greatly diminished in value, by being in too dry a state, and therefore exhausted of a great part of its nutritive juices; and, again, the plants having already accomplished the chief design which nature has marked out for them, by providing for their reproduction, have no power to vegetate again during the same season, with any considerable degree of vigour. In support of the principles here advanced, we may confidently appeal to experience.

It is uniformly the case that meadows which are mown before the seeds are formed, give abundant after crops, and that several of these may be thus obtained during the season. The perennial grasses used for fodder, may in this way be kept in a productive state for many years, whereas their vegetative powers will gradually diminish, and become at length nearly exhausted by the practice of cutting them after the formation of the seed. It is familiarly known to farmers, that an artificial meadow, the grass of which has been always cut at the time of flowering, if it be subjected to tillage, will yield several crops without any application of manure; whereas the same land, if the fodder had been left until after the seed was formed, would be almost wholly unproductive without manuring.

Since plants, when cut at the time of flowering, are less exhausting to the soil, than when this operation is postponed until after the formation of the seed, it has led to an opinion among agriculturists that up to the time of fructification, they are nourished by the constituent principles of the air and of water; and that, subsequent to that period, they draw nearly their whole nutriment from the bosom of the earth.

Doubtless this opinion has arisen from observation of what takes place in the cultivation of artificial meadows, after they have been mown, during a succession of years, at the period when the grass was in flower; and the soil of which, in consequence of this practice, has been so little impoverished, that when

it comes to be brought under tillage, it is capable of producing a crop without any application of manure.

This principle, however, is not applicable to all kinds of plants; lettuce, turnips, tobacco, woad, endive, cabbages, onions and radishes, are highly exhausting to the soil, notwithstanding that they are ordinarily gathered before they have formed their seeds. Potatoes, again, are among the most exhausting plants, though they produce but little seed. Plants transferred from seed-beds, exhaust their original soil more than they do that in which they perfect their growth.

It appears then that plants, during the entire period of vegetation, obtain their aliment from the air, and from the juices and other substances contained in the earth; and that, if they be cut at the time of flowering, the roots and a portion of the stalks, both in a highly succulent state, being left behind, return to the soil nearly all that it has lost; whereas, if the entire plant, including the roots, were removed, the soil would be much impoverished.

It is well known to farmers, that, by ploughing in a crop of grass, or of any kind of annual plants, land is put in a state, without other manure, for the production of a crop. In this case, indeed, more is actually given back to the soil, than it has itself furnished to the plants; since these latter contain, in addition to the juices which they have absorbed from the earth, the various principles which they have decomposed from the water and the air, during the several stages of their growth.

In order to comprehend the principles here laid down, and which I consider of much importance to agriculture, it will be required that we take into consideration the various changes which annual plants undergo during the period of their vegetation. In the first place, then, they develop their leaves, and these, being in contact with the air, draw from it certain principles which have already been mentioned; next the stalks begin to extend, and to put forth a luxuri-

ant foliage, in order that they may be enabled to abstract from the atmosphere an amount of nourishment adequate to the necessities of the plant; the leaves, in the meanwhile, and more especially the stalks, being verdant, strong and succulent, in proportion to the fertility of the soil.

Plants continue in this state until after the period of flowering; at which time they are made to undergo a very striking change. Their roots then begin to wither, and their stalks to change their colour and become dry and shrivelled; until the process of fructification having been at length completed, both the stalks and the roots are but the mere skeletons of what they were, and in this condition contain but few nutritive principles, either for the soil, or for animals.

What then, it may be asked, at this stage of vegetation, has become of the juices which, a short time before, were so abundant in the roots and in the stalks? They have been all consumed in the maturing of the seed. Doubtless, during the process of fructification, the plants still continue to derive from the soil and the atmosphere, certain principles which they convert into nutriment, and which thus partially contribute to the formation of their fruit; still it is not less certain that the juices previously deposited in their organs, have a much larger share in such formation.

These principles are also equally applicable to perennial plants; and when the fruit on trees is too abundant, it is found that they exhibit signs of exhaustion, and produce only small and inferior fruit. The difference between annual plants and these last, is that the former die as soon as they have perfected their seeds, while the roots of the latter still remain fresh, and their leaves verdant, that they may imbibe from the earth and air additional elements of nutrition, which are deposited in their cellular texture to serve as aliment, when the returning warmth of spring causes them to put forth their first vegetation.

M. Mathieu de Dombasle, one of the most enlightened of French agriculturists, has by actual experiment fully confirmed the principles just stated. On the 26th of June, 1820, when the wheat was in flower, he selected within a small compass forty plants of equal vigour and growth, and each with three stalks bearing heads. Twenty of these he pulled up with all their roots, and left the remainder to mature their seed. After carefully removing all the earth from the roots of the gathered plants, and having cut off the stalks about two inches from their neck, he dried separately the roots, and the stalks with their heads.

The roots with the portion of stalk attached to them	weighed	657.91	grains troy
The stalks, heads and leaves		1949.03	“ “

Total	2606.94	grains troy.
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On the 28th of August, at the time of harvest, he pulled the other twenty plants which had matured their seed, and after having separated the roots from the stalks precisely as in the first instance, he obtained the following results:—

The roots weighed	420.07	grains troy
The stalks, heads and chaff	1320.46	“ “
The seed	1027.02	“ “

Total	2767.55	grains troy.
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During the period of two months, the roots with the portion of stalk attached to them had lost

237.84	grains troy
The stalks, heads and leaves	
had lost	628.57 “ “

Total	866.41	grains troy.
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But inasmuch as the seed weighed 1027.02 grains, there had been a total increase of weight of 160.61 grains troy.

We may therefore infer from the results of this experiment, that the juices contained in the stalks and

roots had contributed to the formation of the seed in the proportion of 866.41, the loss on the roots, stalks, etc., to 1027.02, the weight of the seed; and that the difference between these two, being 160.61 grains, or the excess of the weight of the seed over the total amount of loss on the roots, stalks, etc., was absorbed by the plants from the air and soil during the two months of fructification.

If this wheat had been cut at the time it was in flower, one fourth part of the entire weight of the plant would have been left in the soil as manure; whereas a seventh part only is left to subserve this purpose, when grain is cut at maturity. Nor is the quality of this diminished portion to be compared with that of the other; since it contains little else than carbon, while the former abounds in juices, and is much more easy of decomposition. Thus it appears that plants which are left to mature their seeds are by far the most exhausting to the soil, since they return scarcely anything of value to it in the remains of their dry and sapless roots; while those which are cut in a verdant state, give back to it, in their roots and a portion of their stems, not only all that they have taken from the earth, but a part also of the fertilising principles which they have obtained from the atmosphere.

The nutritive principles contained in the soil can be admitted into the organs of plants, only in a state either of solution, or of extremely minute division, in water. Plants in a healthy condition absorb in preference the salts best adapted to their nature; and when water is impregnated with such of these substances as are uncongenial to them, they will refuse to admit them in the same proportion as they exist in this fluid, so that at length it will become quite thick from the quantity of salts thus rejected.

There are certain salts which enter naturally into the composition of particular plants. Thus the pellitory and the nettle are charged with nitrate of potash; and plants that are indigenous to the seashore, con-

tain marine salt or the sulphate of soda ; while the same plants, when removed to a different situation, afford not a particle of these substances, and grow far less luxuriantly. The Marquis de Bullion has shown by analysis that the turnsol, growing in a soil destitute of nitre, does not contain a vestige of that principle ; but after being watered, in the same soil, with a solution of nitrate of potash, he found it to be impregnated with that salt.

If the salts in a soil be too abundant, and of a nature at the same time to be easily soluble, their effect is, generally speaking, injurious and even fatal to plants ; and, especially, if they be of a description not to enter naturally as constituent principles, into their composition. Salts of a character uncongenial to plants can never be useful, except perhaps in very small quantities to stimulate their organs, and excite them to more vigorous action. Hence it is that the sulphate of lime is so extremely valuable in agriculture ; since, in consequence of its being not easily soluble, water never contains but a very small portion of it at any one time ; so that it is never introduced in too large proportions into the organs of plants, and its effects are, for the same reason, prolonged for several years ; until, indeed, as I have already remarked, the soil has become entirely exhausted of it.

The quantity and the nature of the salts present in plants, may be determined by burning the latter in a dry state, and afterward analysing their ashes. It may be useful, however, to state here some facts, which will serve to throw light upon this subject.

Kirwan and Ruckers have shown that herbaceous plants furnish a greater quantity of ashes, than ligneous plants of the same weight ; and Pertuis found that the trunks of trees gave less ashes than their branches, and these latter again less than the leaves. Trees that are green throughout the year yield a smaller proportion of ashes, than those which part with their foliage in autumn. Hales and Bonnet have further

observed, that herbaceous plants transpire water more abundantly, than ligneous; and likewise that the transpiration of trees that are perennially green, is less than that of those which are annually divested of their leaves. Now these facts will serve to explain to us why different plants afford such unequal proportions of ashes. The water which is evaporated by transpiration leaves behind in the cellular texture of the plant, the salts which it brought with it; and, as this process of exhalation goes on, new supplies of water are successively introduced, which, on being evaporated, deposite in turn their salts; and thus it is evident that those plants, and such portions of the same plant, as transpire the most, must necessarily contain the largest proportion of salts.

The salts and earths existing in plants are of the same nature as those contained in the soil in which they grow, though not, as is shown by analysis, in the same proportions; since plants have a preference for particular salts, and therefore absorb a greater or less quantity of them according as they are suited to their particular constitution, and as they are, besides, more or less soluble in water.

We would not be understood to say, that all the salts présent in plants have had a previous existence in the soil; for certain neutral salts are undeniably formed in the organs of plants; those, for instance, the acid composition of which is known to us, and especially such as contain a constituent vegetable principle. The acetates, malates, and citrates are of this number. These salts, however, no longer exist in the ashes of plants; since their acid is entirely decomposed by the action of fire, and their base, which is nearly always potash or lime, is alone preserved. To ascertain, then, if they be present, we must employ the humid method of analysis.

We may trace the acid formation in some of these salts, by merely watching the progress of vegetation, and observing the changes which take place in its prod-

ucts. Of this I will mention a single example. The beet root in the north and in the south of France, though it be gathered at precisely the same time in autumn, does not yield the same products; that of the north containing sugar, and the other saltpetre. And still that which is grown in the south, according to experiments made with great care by M. Darracq, in the department of Landes, affords as much sugar as the other, when gathered in the month of August, or early in September. The sugar, therefore, is in this case displaced by saltpetre, the acid of which is formed in the progress of vegetation. It has also been frequently noticed that beet roots containing sugar, undergo a change during the winter; this substance, as in the instance above, being supplanted by saltpetre. In this latter case the phenomena of decomposition are, indeed, so obvious, that we may almost trace them through their successive stages, by the eye. The juice of the beet root, when poured into the boilers after it has begun to change, gives out a great quantity of white froth, from which arise reddish vapours of nitrous gas; in which state of the liquid, it becomes difficult to extract the sugar and complete the boiling; this substance crystallizing badly, and the treacle being very abundant. Now, in this condition of things, it is evident that there has already taken place a combination of oxygen and nitrogen, and that it is only required that there should be some addition to the former in order to produce nitric acid; and this additional quantity is supplied, during the successive changes which the beet root undergoes in the process of vegetation. As fast then as the nitric acid is thus formed, it combines with the potash which is found to exist in this root in the proportion of one hundredth part of its weight, and by means of such combination produces saltpetre.

In taking notice of plants, we observe a great difference in their odour, taste, consistence, etc., at different periods of their vegetation; from which it follows

that they must form new combinations and new products, and, consequently, new salts.

In green herbaceous plants, the alkaline salts abound the most. According to the observations of de Saussure, the ashes of certain young plants which grew upon a sterile soil, contained at least three fourths of their weight of alkaline salts; and those also of the leaves of trees, when newly starting from their buds, contained not less than one half.

The proportion of alkaline salts is diminished as plants become larger and older; and this remark is applicable not only to annual plants, but to the leaves also of deciduous trees.

The ashes of seeds abound more in alkaline salts, than those of the plants by which they have been produced.

The facts here stated are highly important to persons who are employed in the manufacture of potash and other salts, from the ashes of vegetable substances; since they show that it is far from being a matter of indifference, whether they make use of the ashes of all kinds of plants, indiscriminately, or of those obtained from them in all the different stages of their growth.

The earthy phosphates of lime and magnesia, next to the alkaline salts, are the most abundant in plants; and, as has been noticed with regard to the latter, their quantity diminishes in proportion as plants advance in age.

Besides the substances already enumerated, plants contain also silica and certain of the metallic oxydes, especially those of iron.

ARTICLE VI.

Recapitulation of the Phenomena of Vegetable Nutrition.

Plants obtain their nutriment principally through the leaves and roots. The organs of the first absorb from the atmosphere oxygen and carbonic acid gas,

and water ; while those of the latter imbibe the same gases from the soil, both as they exist in a free state and dissolved in water—and the juices and salts also, which are contained in that liquid.

Water appears to be a necessary vehicle to convey to plants the different nutritive principles furnished by the soil. Thus this fluid not only contributes its own elements to their nourishment, but it also supplies them with the different earthy and saline principles necessary to their vegetation.

The substances which afford to plants their principal nutriment, are composed entirely of carbon, hydrogen and oxygen ; and the numerous products formed by plants in the different stages of vegetation, are found by analysis to consist of those elements ; the salts, the earths, and the metals, being present only in very small proportions, and in a state somewhat different from that in which they exist in the soil.

Oxygen, carbon, and hydrogen, which are the three great principles essential to the growth of plants, combine in very different proportions among themselves ; and it is this which occasions the almost infinite diversity observable among the products of the vegetable kingdom ; a few hundredths more or less of oxygen, carbon or hydrogen, being sufficient to give a new character and appearance to bodies.

Chymistry, by operating on dead vegetable substances, can produce, at will, some of these effects ; while fermentation and spontaneous decomposition offer to our consideration a much greater number. But the unvarying character of the products of plants of the same species, the analogy existing between those of different species of the same genus, their dissimilarity in the various organs, and the composition, apparently so complicated, peculiar to each, present to us, altogether, a series of natural phenomena, entirely beyond the power or ingenuity of art to explain.

We are acquainted with the substances which pass

into plants, and with those which they give out; and we can also determine by analysis, the nature and the composition of the various products which they form; but beyond this our limited faculties seek in vain to penetrate. All that takes place within the plant is to us, as yet, a profound mystery, and appertains to that hidden power of vitality, to which are subject the physical laws of which we have a knowledge.

And still, as the laws of vitality which govern the vegetable kingdom, are, in their application, less independent of physical agents, than those which regulate the living functions of animals, we are enabled even now to lift a portion of the veil, and, at least, to trace the course of the progressive changes which take place in plants, though we can neither produce them ourselves, nor comprehend by what mode of action they are effected.

As to the germination of seeds, and the unfolding of buds in the spring, they are scarcely anything more than the effect of physical laws, the agency of oxygen being all that is required to produce them; for though both water and heat are necessary as auxiliaries, neither of them in any way enter into the new combinations which take place, and they merely co-operate in facilitating the changes which are produced. The oxygen in this case unites with carbon, and forms carbonic acid gas; and by this means the mucilage and starch are converted into a milky liquid, which serves as the first nutriment to the nascent plant.

As soon as the leaves are developed, and the radicles begin to shoot forth and penetrate the soil, the course of nutrition becomes entirely changed. The oxygen gas, during the night, is constantly abstracting carbon from all parts of the plant; but the carbonic acid gas which is by this means given out, instead of remaining in the atmosphere, as at the period of germination, is absorbed for the most part by the

roots and leaves, and in the organs of the latter is decomposed by the help of solar light; the carbon in the meanwhile remaining fixed in the plant, while the oxygen is thrown off in the form of gas.*

* The popular opinion, that when the leaves of vegetables perform their healthy functions, they tend to purify the atmosphere in the common variations of weather, and changes from light to darkness, is confirmed by experiment.

In germination, and at the time of the decay of the leaf, oxygen must be absorbed; but when it is considered how large a part of the surface of the earth is clothed with perennial grasses, and that half of the globe is always exposed to the solar light, it appears by far the most probable opinion, that more oxygen is produced than consumed during the process of vegetation; and that it is this circumstance which is the principal cause of the uniformity of the constitution of the atmosphere.

Animals produce no oxygen gas during the exercise of any of their functions, and they are constantly consuming it; but the extent of the animal, compared to that of the vegetable kingdom is very small; and the quantity of carbonic acid gas produced in respiration, and in various processes of combustion and fermentation, bears a proportion extremely minute to the whole volume of the atmosphere: if every plant during the progress of its life makes a very small addition of oxygen to the air, and occasions a very small consumption of carbonic acid, the effect may be conceived adequate to the wants of nature.

It may occur as an objection to these views, that if the leaves of plants purify the atmosphere, toward the end of autumn and through the winter, and early spring, the air in our climates must become impure, the oxygen in it diminish, and the carbonic acid gas increase, which is not the case; but there is a very satisfactory answer to this objection. The different parts of the atmosphere are constantly mixed together by winds, which, when they are strong, move at the rate of from sixty to a hundred miles in an hour. In our winter, the southwest gales convey air which has been purified by the vast forests and savannahs of South America, and which, passing over the ocean, arrives in an uncontaminated state. The storms and tempests which often occur at the beginning, and toward the middle of our winter, and which generally blow from the same quarter of the globe, have a salutary influence. By constant agitation and motion, the equilibrium of the constituent parts of the atmo-

And another source of the nourishment of plants is the aqueous fluid, of which a greater or less quantity is at all times contained in the atmosphere, and which by the diminished temperature of the night is disengaged from it, and precipitated in the form of dew. The water in the soil, also, after dissolving the juices of its manures, conveys them to the organs of plants.

But it is not enough, in order that plants should flourish, that they be supplied merely with necessary aliment; it is required, furthermore, that the different nutritive substances which they absorb, should be elaborated and digested by their organs, and in this process they must be assisted by other agents, which are no less essential than food to a vigorous and healthy vegetation.

It has been already observed that leaves transpire oxygen gas, only when their surfaces are acted upon by the rays of the sun; so that the carbonic acid absorbed by them and by the roots, remains in the plant so long as the solar rays are obscured. This fact has been clearly ascertained, and it explains to us some of the most interesting and important phenomena of vegetation. We discover in it the reason why, when plants grow in the shade, the fruits and juices have no longer the same taste, or perfume, or consistence, as those of the same plants, when growing in the sun; and why, also, herbaceous and leguminous plants are always of inferior quality, whenever, from any cause, they are deprived of the solar light to assist them in the decomposition of carbonic acid, and the elaboration of the nutritive elements.*

sphere is preserved; it is fitted for the purposes of life; and those events which the superstitious formerly referred to the wrath of Heaven, or the agency of evil spirits, and in which they saw only disorder and confusion, are demonstrated, by science, to be ministrations of Divine Intelligence, and connected with the order and harmony of our system.—*Davy's El. Ag. Chym.* pp. 215, 216.

* Shrubs and trees, on the contrary, which are too much sheltered, too much secluded from the sun and wind, extend

But in addition to the action of solar light, so indispensable to the healthy growth of plants, they require likewise a certain degree of heat. Generally speaking, their germes do not begin to unfold in the spring, until the atmosphere has reached a temperature of from 50° to 54° Fahrenheit; and vegetation becomes the more luxuriant in proportion as the atmospheric heat increases; provided, however, that the earth in the meanwhile contains so much moisture, that its nutritive juices can be conveyed by the water to the organs of plants, and thus keep up in them a plentiful transpiration. The influence of temperature upon vegetation is indeed of so marked a character, that the latter is perceived uniformly to decline, whenever there is a diminution of atmospheric heat; and to recover its previous energy so soon as the temperature is again increased. The effect of heat upon plants is to expand their sap and facilitate its circulation; while that of cold is to render this fluid thick and viscid, and to cause it to stagnate in their organs.

But whatever may be the degree of atmospheric temperature, if plants be deprived of solar light and the aqueous fluid, their vegetation becomes less vigorous, and their growth is retarded. We perceive, then, that besides being liberally supplied with the elements of nutrition, plants require certain agents to

exceedingly in height, but present at the same time slender and feeble branches; their leaves are pale and sickly, and in extreme cases they do not bear fruit. The exclusion of light alone is sufficient to produce this species of disease, as would appear from the experiments of Bonnet. This ingenious physiologist sowed three seeds of the pea in the same kind of soil: one he suffered to remain exposed to the free air; the other he enclosed in a tube of glass; and the third in a tube of wood. The pea in the tube of glass sprouted, and grew in a manner scarcely at all different from that under usual circumstances; but the plant in the tube of wood, deprived of light, became white and slender, and grew to a much greater height.—*Davy's El. Ag. Chym.* pp. 243, 244.

co-operate with them in order that they may suitably elaborate and concoct these elements.

In a soil containing an over-supply of manure, and especially if it be such as is easy of solution, so that the water will convey it abundantly to the plants, these may, indeed, be thus made to acquire a prodigious growth; but unless these substances so bountifully furnished, be at the same time, properly assimilated by the concurrent action of solar light and heat, and the digestive organs of the plants, whatever may be the size these latter attain, it will only be as I have already remarked, a sort of morbid obesity, and none of their products will have either the taste or odour they would have acquired, had the nutriment been less in quantity, and more perfectly digested. It is not unfrequently the case that, under such circumstances, fruits and the products of leguminous plants, retain the peculiar smell and savour of the manure by which they have been nourished.*

The juices of plants circulate, not, indeed, with the same regularity of movement that is observable in animals, with their more perfect organization, but, still, with a degree of force sufficient to distribute them through all the different organs, in order to undergo in each one of these an appropriate elaboration.

The roots imbibe the juices contained in the earth, by means of their capillary tubes; but the force by

* Plants vegetating in peaty soils, or in lands too copiously supplied with animal or vegetable matter, rapidly expand, produce large bright green leaves, abound in sap, and generally blossom prematurely.

Where a land is too rich for corn, it is not an uncommon practice to cut down the first stalks, as by these means its exuberance is corrected, and it is less likely to fall before the grain is ripe: excess of poverty, or of richness, is almost equally fatal to the hopes of the farmer; and the true constitution of the soil for the best crop is that in which the earthy materials, the moisture and manure, are properly associated; and in which the decomposable vegetable or animal matter does not exceed one fourth of the weight of the earthy constituents.—*El. Ag. Chym.* p. 244.

which these juices are propelled through the internal organs of the plants, so that they reach even the leaves where their carbon is made to combine with oxygen gas, is too great to be attributed merely to capillary attraction* or the pressure of the atmosphere.

* Capillary attraction can only be exerted by the surfaces of small vessels, and can never raise a fluid into tubes above the vessels themselves.

Mr. Knight is of the opinion, that the contractions and expansions of the silver grain in the alburnum are the most efficient cause of the ascent of the fluids contained in its pores and vessels. The views of this excellent physiologist are rendered extremely probable by the facts he has brought forward in support of them. Mr. Knight found that a very small increase of temperature was sufficient to cause the fibres of the silver grain to separate from each other, and that a very slight diminution of heat produced their contraction. The sap rises most vigorously in spring and autumn, at the time the temperature is variable; and if it be supposed that, in expanding and contracting, the elastic fibres of the silver grain exercise a pressure upon the cells and tubes containing the fluid absorbed by the capillary attraction of the roots, this fluid must constantly move upward toward the points where a supply is needed.

The experiments of Montgolfier, the celebrated inventor of the balloon, have shown that water may be raised almost to an indefinite height by a very small force, provided its pressure be taken off by continued divisions in the column of fluid. This principle, there is great reason to suppose, must operate in assisting the ascent of the sap in the cells and vessels of plants which have no rectilineal communication, and which everywhere oppose obstacles to the perpendicular pressure of the sap.

The changes taking place in the leaves and buds, and the degree of their power of transpiration, must be intimately connected likewise with the motion of the sap upward. This is shown by several experiments of Dr. Hales.

A branch from an apple-tree was separated and introduced into water, and connected with a mercurial gauge. When the leaves were upon it, it raised the mercury by the force of the ascending juices to four inches; but a similar branch, from which the leaves were removed, scarcely raised it a quarter of an inch.

It will be proper to mention the facts which show, that in

The celebrated Hales cut a branch from a vine that was four or five years old, and carefully cemented the end of it in a glass tube bent in the form of a syphon, and filled with mercury; when at the end of a few

many cases fluids descend through the bark. Mr. Knight has shown, in the Philosophical Transactions, that long strips of bark, everywhere detached from the alburnum of the tree, except at their upper ends, deposited as much alburnum as they could have done if they had retained their natural position. In these cases, the sap must have descended through the bark wholly.

M. Baisse placed branches of different trees in an infusion of madder, and kept them there for a long time. He found, in all cases, that the wood became red before the bark; and that the bark began to receive no tinge till the whole of the wood was coloured, and till the leaves were affected; and that the colouring matter first appeared above, in the bark immediately in contact with the leaves.

Similar experiments were made by M. Bonnet, and with analogous results, though not so perfectly distinct as those of M. Baisse.

Du Hamel found, that in different species of the pine and other trees, when strips of bark were removed, the upper part of the wound only emitted fluid, while the lower part remained dry.

This may likewise be observed in the summer in fruit trees, when the bark is wounded, the alburnum remaining untouched.

The motion of the sap through the bark seems principally to depend upon gravitation. When the watery particles have been considerably dissipated by the transpiring functions of the leaves, and the mucilaginous, inflammable, and astringent constituents, increased by the agency of heat, light, and air, the continued impulse upward from the alburnum forces the remaining inspissated fluid into the cortical vessels, which receive no other supply. In these, from its weight, its natural tendency must be to descend; and the rapidity of the descent must depend upon the general consumption of the fluids of the bark in the living processes of vegetation; for there is every reason to believe that no fluid passes into the soil through the roots; and it is impossible to conceive a free lateral communication between the absorbent vessels of the alburnum in the roots, and the transporting or carrying vessels of the bark; for if such a communication existed, there is no reason why the sap should not rise through the bark as

days, he found that the mercury had risen by the ascending force of the sap alone, to the height of thirty-eight inches. Mirbel repeated this experiment with similar results; and has likewise added many

well as through the alburnum; for the same physical powers would then operate upon both.

Some authors have supposed that the sap rises in the alburnum, and descends through the bark, in consequence of a power similar to that which produces the circulation of the blood in animals; a force analogous to the muscular force in the sides of the vessels.

This analogy has, however, in general, been too much insisted upon and too loosely stated; there are undoubtedly resemblances more or less remote in every part of created nature; but the irritability of the muscular fibre in animals and the contractibility of the vascular system in plants appear to depend upon entirely different causes.

In crystallization, or the regular arrangement of inorganic substances, there is a constant increase of matter from the attraction and juxtaposition of like parts or molecules. In vegetation a germ expands by the assimilation of a variety of new aliments, and by powers entirely different from those of common inorganic matter; but there seems to be no system of nerves, as in animals, which is essential to irritability. We know so little of the refined powers and properties of matter, that we can give little more than vague hypotheses as to the cause of the movement of the fluids in the vegetable cells or tubes; yet it is impossible not to allow common material agents a much greater share in producing this phenomenon, than they exercise in animal life.

Whoever will peruse any considerable part of the *Vegetable Statics* of Hales, must receive a deep impression of the dependence of the motion of the sap upon physical causes. In the same tree, this sagacious person observed that in a cold cloudy morning, when no sap ascended, a sudden change was produced by a gleam of sunshine of half an hour, and a vigorous motion of the fluid. The alteration of the wind from south to the north immediately checked the effect. On the coming on of a cold afternoon after a hot day, the sap that had been rising began to fall. A warm shower and a sleet storm produced opposite effects.

Many of his observations likewise show that the different powers which act on the adult tree, produce different effects at different seasons.

Thus in the early spring, before the buds expand, the varia-

others of his own of great importance, in relation to the same point; the description of which, however, would take us too far away from our subject.

The sap circulating in plants through their numerous vessels and cells, and these having no rectilinear communication with each other, its ascending force may be explained by a principle resulting from the interesting experiments made by M. de Montgolfier. This philosopher has shown that by means of a very inconsiderable force liquids may be raised to almost indefinite heights, provided that the pressure of their

tions of the temperature, and changes of the state of the atmosphere with regard to moisture and dryness, exert their great effects upon the expansions and contractions of the vessels; and then the tree is in what is called by gardeners its bleeding season.

When the leaves are fully expanded, the great determination of the sap is to these new organs. And hence a tree which emits sap copiously from a wound while the buds are opening, will no longer emit it in summer when the leaves are perfect; but in the variable weather, toward the end of autumn, when the leaves are falling, it will again possess the power of bleeding in a very slight degree in the warmest days: but at no other times.

In all these circumstances there is nothing truly analogous to the irritable action of animal systems.

In animal systems the heart and arteries are in constant pulsation. Their functions are unceasingly performed in all climates, and in all seasons; in winter, as well as in spring; upon the arctic snows, and under the tropical suns. They neither cease in the periodical nocturnal sleep, common to most animals; nor in the long sleep of winter, peculiar to a few species. The power is connected with animation, is limited to beings possessing the means of voluntary locomotion; it co-exists with the first appearance of vitality; it disappears only with the last spark of life.

As the operation of the different physical agents upon the sap vessels of plants ceases, and the fluid becomes quiescent, the materials dissolved in it by heat are deposited in the cells of the alburnum; and in consequence of this deposition, a nutritive matter is provided for the first wants of the plant in early spring, to assist the opening of the buds, and their expansion, when the motion from the want of leaves is as yet feeble.—*Davy's El. Ag. Chym.* pp. 225—231.

column is taken away by the interposition of numerous partitions or valves.

The force with which sap ascends is increased in proportion to the healthiness and vigour of the plant, and as its transpiration is more copious and uniform. A branch stripped of its leaves raises the mercury to a less height, than one still retaining its foliage; and trees with leaves that are spongy and soft, and full of exhaling pores, as, for example, those of the wild quince, the alder, the sycamore, the peach, the cherry, etc., elevate it higher than do those, the surfaces of whose leaves are either glazed, or dry, as in the case of the evergreens. These facts are obtained from the beautiful experiments of Hales.

All the water absorbed by the different organs of plants, and that, especially, which is taken up by the roots, is forthwith employed in diluting the juices, and thus facilitating their circulation. A portion of this fluid is afterward disengaged, and furnishes by its decomposition, the hydrogen so abundant in the various products of vegetation; the greatest part of it, however, is exhaled, and principally by the leaves, the temperature of which is thus kept somewhat below that of the atmosphere during the scorching heat of summer. A sunflower observed by Hales, transpired by its leaves in the space of twelve hours, one pound and fourteen ounces of water.

The cold which begins to be felt in autumn, checks and renders more sluggish the movement of the sap. The fluids of plants are now gradually thickened, their solids contract, their leaves cease to inhale, their roots no longer absorb the juices of the soil, and at length every vital function is suspended. But the returning warmth of spring imparts new life to their organs; both their fluids and solids become at this season greatly expanded; a fresh impulse is given to their circulation, and the nutritive elements deposited in their cells and membranes at the close of the prece-

ding summer, and during the early part of autumn, supply them with their earliest aliment.

Trees cut in the winter, and branches which have been separated at this season, from their parent trunk, put forth buds and shoots in the spring. If a branch of a vine, without being detached from its stock, be conducted into a green house during winter, it will there vegetate as in the summer; while the part remaining without exposed to the cold, undergoes no change. Plants that have been browsed by cattle in the autumn, vegetate more slowly and with less vigour in the spring, than do those the roots and neck of which have not been lacerated and torn, from their having been cut with the scythe at the gathering in of the crops.

The fact is familiar to all agriculturists that young trees, on being transplanted in the spring, frequently vegetate for three or four months, and then suddenly die. By examining the roots of such trees, it will in almost every case be found, that there is not left the smallest sign of vegetation; which proves that this process has been for some considerable time carried on, only through the juices which had been deposited in the plants, before the fall of the leaf during the preceding autumn.

But a fact familiar to every observer is the difference in the vegetation of the two parts of the same branch, the one being in the ground, and the other in the air. That part which is buried in the soil puts forth roots, while the other which rises into the atmosphere, produces leaves; and if a portion of the root be uncovered, and brought into contact with the air, it will also put forth both shoots and leaves; while the remaining portion left in the earth continues, as before, to vegetate only by sending out roots.

Thus the different parts of plants are so organised by vegetation, as to absorb at the same time and in the most convenient manner, both from the soil and

the atmosphere, the nutritive principles respectively contained in each.

Art has arrived at means to control the flow of the sap, and to regulate its circulation at will. When the juices contained in the soil are too abundantly absorbed, the consequence is that they are elaborated very imperfectly, and merely serve to increase the size of the plant. Trees, more especially, will produce, in this case, neither flowers nor fruit; but, to make use of an expression in common use, they merely *push into wood*. To remedy this excessive supply of sap, so that there shall be no more than what the tree can perfectly digest, a portion of the roots are sometimes taken off, and even incisions are made in the bark to let off the surplus of this fluid.

To increase the size and improve the quality of fruits, it is a common practice to take away either a portion of the branches, or of the fruit itself, in order that an increased quantity of sap may be diverted to that which remains; and by applying tight ligatures to the branches, or by means of circular incisions through the entire thickness of the bark, we may produce the same results.

The object in pruning fruit-trees is that their products may be limited, and in such quantity only as the tree shall be able to nourish and perfect.

The operation of grafting which is performed by inserting a scion from one tree into a branch of another of kindred species, is merely presenting to the latter, an organic texture different from its own; and in passing through the vessels of which, the juices of the stock undergo a certain elaboration, which changes the nature of their products.

It is neither by analysis, nor by the proportions of such principles as may be extracted by water, that we can judge of the nutritive properties of plants, and of other alimentary substances. I have already shown that a nutritive substance, after being deprived by water of all its soluble portions, may, in the prog-

ress of its decomposition, still continue to afford new soluble compounds. It is only by experience, and by observing the effects of particular kinds of nutriment upon animals, that we can ascertain and determine their different alimentary powers. The digestive fluids in the stomach of animals and in the organs of plants, acted upon by vital forces, with regard to the nature and operation of which we are as yet entirely ignorant, have also their chymistry; of which, again, we are in the same state of uncertainty and darkness as to everything beyond merely their effects.

It is surely erroneous then, to undertake to determine the quantity of nutriment which any substance contains, merely by such portion as may be extracted by water. Adopting the principle here condemned, Davy assigns to the beet root a nutritive power which he designates by the number 136, and to the carrot another which he represents by 98; while Thayer, in the experiments made by him, places that of the former at 57, and of the latter at 98. Upon the same principle, Davy estimates the nutritive properties of linseed cakes at 151, compared with those of beet root at 136; while it has been demonstrated, that sixty pounds of the beet scarcely contain as much nutriment, as ten pounds of linseed cake.

In judging of the nutritive power of any substance, we should have less regard to its chymical principles, than to the particular nature of the animal which it is employed to nourish; since one will reject what is eaten with avidity by another, and some animals readily digest what others will not so much as taste; so that it is by observation alone, that these matters can be determined.

But these principles are still less to be depended on, in relation to the nutrition of vegetables, than with regard to that of animals; since the former require their aliment, in a state either of solution or of mixture with water, to be brought to them, and placed in immediate contact with their organs, while the lat-

ter move about and seek their food wherever it is to be found, and select only the particular kinds which suit them best; but the actual nutritive power of the different alimentary substances in both these cases, must be estimated by the results of their elaboration in the digestive organs, and by the effects produced by them on the animal and vegetable economy. It should further be recollected, that the nutritive properties of vegetable products depend not so much upon their weight, as upon their quality; and that even though a substance be entirely insoluble in water, it may, nevertheless, be decomposed by the gastric juices, and converted into highly nutritious aliment.

CHAPTER VII.

On the Amendment of Soils.

[FROM CHAPTAL'S CHYMISTRY APPLIED TO AGRICULTURE.]

To amend a soil is so to change and meliorate its character, as to render it better adapted to vegetation.

Everything, therefore, the tendency of which is to dispose soils to be more favourable to the growth and maturing of plants, in connexion with the concurrent influence of the atmosphere, water, temperature, manures, &c., may, in relation to this subject, be properly termed *amendment*.

It will be apparent then, that we must first of all be made acquainted with the qualities of soils, and especially, with their defects, before we can intelligently take a single step towards their amendment; since it is by means of such knowledge alone, that we can be enabled to apply to it the particular culture, and the meliorating substances which it requires. And this initiatory step of ascertaining the defects of a soil, implies that we should also understand the na-

ture of the various agents that are to be employed in its amendment; for the faults of a soil being once ascertained, the next step is to correct them; and there are no other means of doing this than by the employment of substances possessing contrary properties.

In thus including under the general name of amendment, everything that may be made in any way to contribute toward the melioration of soils, it will be perceived that we allow to the term a very extensive application; since it will be thus made to comprehend not only the mechanical operations connected with the soil, and the various nutritive and earthy mixtures which may be artificially prepared, but likewise every kind of means which can in any way be employed to turn to better account the action of the atmosphere, of water, heat, &c. It is in reference to all these several relations, that this great subject of amending the soil should be considered.

The very best soils require to be laboured either with the spade, the mattock, or the plough, before they can be made productive. By this operation the earth is rendered light and friable, such nutritive substances as have been carried down by rains too deep for the roots of plants to be benefited by them, are brought to the surface, the manures of every kind are thoroughly mixed with the soil, and their action is rendered more regular and uniform. It also destroys noxious weeds, converting them at the same time into nutriment for the useful plants, and rids the soil of insects, which would otherwise be in such numbers as greatly to injure, and even destroy the crops.

All soils, whatever may be by their quality, require to be subjected to this operation. It constitutes, indeed, the very basis of agriculture, since without it there can be no remunerating product, no successful harvest. The mattock and spade, and more especially the latter, are better for this purpose than the plough, inasmuch as they turn over, and mix, and divide the soil more thoroughly. Whatever pains may be taken

in tilling lands with the last-named instrument, even by repeated operations both of parallel and cross ploughing, there will still be intervals between the furrows, where a portion of the soil will have escaped being turned up; and still, inasmuch as tillage with the plough is both cheaper and more expeditious, it is generally preferred.

I am acquainted with a small village in Touraine, between the Cher and Loire, where the soil is cultivated altogether with the spade, and the products of which are as large again as those of other land in the same neighbourhood; the inhabitants have consequently become rich, and their lands have doubled in value. In Bremont also, between Loches and Chinon, the soil which is very fertile, is cultivated entirely by this means. Still it must be admitted that this mode of culture is suited only to small estates, or countries where labour is very abundant and cheap; though, doubtless, in many cases it might from time to time be profitably resorted to, to meliorate the condition of the soil, and more especially in the cultivation of plants with long roots, or where such plants have already exhausted the fertility of lands to a considerable depth.

The proprietors of the alluvial lands formed by the deposits of the Loire, between Tours and Blois, after obtaining from them a crop of grain, lease them immediately to individuals, who turn up the soil to the depth of twelve inches with the spade, and raise upon it the same year a crop of leguminous plants.

It will be perceived from the nature of the effects produced by tillage, that it would be improper to repeat this operation equally often or to carry it to the same depth in all soils, or to resort to it indifferently at all seasons of the year. A light porous soil, whether calcareous or sandy, requires less tillage than one that is compact, and of an argillaceous character; and this latter needs also to be worked to a greater depth, that the roots of plants may freely extend themselves,

and that the air may be admitted in order to deposite its fertilizing moisture.

Calcareous, sandy and siliceous soils admit of tillage at any time; while those of an argillaceous nature should be ploughed only when they are in a particular state; and these seasons the farmer must lose no time in improving. Lands of this latter description are so soft and adhesive immediately after rain, that to attempt to till them at such time is little better than tracing lines in the mud; whereas, on the other hand, they become so hardened by a few days only of dry weather afterward, as to be scarcely penetrable by the plough. It is only in the intervals between these two extremes, that such soils can be advantageously worked.

The most careful and judicious ploughing does not always suffice suitably to prepare lands for a crop. In some instances the soil will not have been enough divided to render it loose and friable; in others it will not have been sufficiently raised up, or will be left perhaps in a very irregular and uneven state; and it is, according to circumstances, either by the harrow or the roller, that the tillage in such cases must be completed.

By passing the harrow in every direction over a fresh-ploughed field, the clods which have been left on the surface are broken, the loosened weeds are dragged out, and every part of the soil is equally stirred and divided. The power and weight of this instrument should be adapted to the nature of the soil, and the force required to pulverize it.

The harrow may be also very usefully employed in scratching and loosening the surfaces of artificial meadows, whenever they have become hard and impenetrable to the air and water. This operation, however, should not be repeated oftener than every second year, and should always be performed either early in the spring, or immediately after the first mowing. By this practice the weeds may be in a

great measure destroyed, and meadows which otherwise would be constantly growing worse, reclaimed, and rendered again productive.

I have myself experienced great advantage in passing the harrow over fields of winter grain, early in the spring; the crops growing altogether more luxuriantly where this operation had been performed. In this latter case, however, only a very light harrow, and with wooden teeth, should be employed.

The roller also may be used with excellent effect, immediately after the seed is covered. It compacts and levels the surface of the soil, and brings the earth in contact with the seed; and is especially serviceable in lands of a loose and porous nature and the constituent particles of which are very light and fine. When this operation is neglected to be performed on such soils, their surface is liable to be carried away both by rains and wind, so that the roots of the plants shall be left exposed and bare. A still further advantage derived from this practice, is that the surface of the ground is made smooth and even, so as to present no obstacles to the scythe or sickle, at the time of harvest.

When the surface either of fields under tillage, or of meadows, has been raised up by freezing, so that when it comes again to thaw, the roots of the plants are left detached from the soil, and consequently almost entirely without support, there is a great advantage in employing the roller the moment the land becomes sufficiently firm to admit of its use, since in this way the earth is again brought into contact with the roots, and the injurious effects of the frost are thereby prevented.

In order to determine what substances are best adapted to meliorate the condition of a particular soil, we must first, as has been before remarked, be made acquainted with its nature and its defects. Soils already consisting of a suitable mixture of all the necessary earths, require of course, no new earthy prin-

ciples to be added to them; so that faithful tillage, combined with the judicious application of manure, is all that is needed to render such soils productive. But where, on the contrary, we find a soil in which a single earth so predominates as to impart its character to the entire mass, there is then no other way of correcting its defects, but by the addition of substances possessing opposite properties.

Soils may be classed under these four general heads, viz.: argillaceous, calcareous, siliceous, and sandy; and this division appears to comprehend in it all the different kinds which require to be amended; the particular substances suitable to be employed in this operation, being in all cases sufficiently indicated, by the character of the predominating earth.

Argillaceous soils are rendered clammy and tenacious by rain; and, again, they become hard and full of fissures from the effect of drought. They absorb the humidity of the atmosphere only on their surface; and, at the same time that they imbibe abundantly the water which falls in rain, in consequence of their strong affinity for this fluid they retain it so tenaciously, that whenever there is a great quantity of it present, it remains in a stagnant state, and decomposes and rots the roots of plants.

Soils of this character are but little favourable for agricultural purposes. At the time they are bound up by the winter cold, the water contained in their fissures expanding as it freezes, separates and raises up the earth, and this being succeeded by a thaw, the soil is left in a broken state, and divided into small particles in such manner that the roots of plants have so little connexion with it, that they may be drawn out almost without any resistance; so that they are by this means left in the situation of a plant just set out, and before its roots have become established and fastened in the soil to enable it to vegetate. If then the roots, while in this condition, be again exposed to frost, its effects must necessarily prove fatal; since,

being no longer protected by adhesion to the earth, the cold acts upon them without mitigation, and similar to what it would, if they lay uncovered upon the surface. It is for this reason that alternate freezing and thawing is more injurious to meadows and to the cereal plants, than uninterrupted cold, be it ever so severe, that continues until the spring. To obviate, therefore, the evil to be anticipated from a second freezing, I would recommend that the soil be pressed down and compacted by the roller, after the first thaw.

The question arises then, what means shall be employed to remedy these defects, so remarkable in soils of an argillaceous nature. Whatever tends to render the earth more moveable, and porous, and light, must be beneficial to such soils. Thus a mixture of the different earths, calcareous sands, remains of shells, chalks and the lean marls, deep and frequent ploughings, the turning in of green crops, manures of a heating nature, as the dung of sheep and horses, mixed with litter and in a fresh and unfermented state, also that of pigeons and domestic fowls, the salts, poudrette, &c., are all suitable for the amendment of such soils.

I have likewise seen soils, which were characterized by all the defects above described, and which, at the same time, were not of an argillaceous character. By diluting portions of these soils in water, I have found them to be wholly destitute of coarse sand or gravel, and to consist entirely of particles so excessively small as to give no consistence to the mass, and which formed a mere paste with water, that contracted and cracked as soon as that liquid was withdrawn by evaporation. The only difference between argillaceous soils and these, is that the latter, in a dry state, do not possess the hardness of clay, but, on the contrary, crumble into an almost impalpable powder, when they are pressed by the hand. The peculiar condition of these soils I consider to be owing to exhaustion, from long-continued culture. I have myself

had soils of this character, which I have succeeded in restoring to fertility, by applying to them a mixture of marl, containing forty-two per cent. of siliceous gravel.

Calcareous lands are distinguished by properties and defects very different from those of such soils as are composed chiefly of clay. Water filtrates readily through them, and is also evaporated with the same facility. They are likewise in a high degree accessible to the air, so that this fluid can freely deposite within them the moisture with which it is charged, and which, especially in warm climates, contributes greatly to their fertility. Soils of this kind are at all times easily worked; and being loose and porous, provided they be of sufficient depth, they permit the roots of plants to develop and extend themselves without any impediment.

Although this description of soil does not require amendment to the same extent as that previously described, still it may be improved, and especially by so changing its composition as to render it more retentive of moisture, for the use of the plants which grow upon it. For this purpose it is sufficient to mix with it a portion of fat marl, or if this substance cannot be procured, of calcined clay.

Soils of this kind are naturally warm, and therefore the fresh dung of neat cattle, and manures of an unctuous nature suit them best. An application of fine sand is also highly improving to calcareous soils, and especially if it be mixed either with clay or with fat marl. I have seen, too, the mud of rivers very successfully employed in amending these soils.

Sandy and siliceous soils in many of their properties closely resemble each other. Both have generally been formed by the alluvial deposits of rivers; and they are both almost entirely steril, except they contain some other earthy principles; while they both afford the basis of an excellent soil, with suitable amendment.

When these last-mentioned soils have been formed by the inundations of rivers, or in consequence of these latter changing their beds, they acquire no fertility for some considerable time. But by being occasionally flooded by the overflowings of rivers, which leave upon their surface a deposit of mud, and this becoming gradually incorporated with them, so that, in addition to its fertilizing properties, its effect is to bind their loose particles together, they are in time converted into excellent soils. The mud of rivers is the more fertilizing, inasmuch as it is mixed with all sorts of vegetable and animal remains, which the turbid waters bear along with them during the periods of their inundation. It is owing to the fertility in this way imparted to alluvial soils, that we see them covered with a luxuriant herbage which springs up spontaneously, and wholly without culture; the waters at seasons of flood depositing upon them the various seeds which they bear along with them in their course.

Soils of this description rarely require manure; since every successive inundation brings with it new fertilizing ingredients. This process constantly going on, the surface of the soil is gradually elevated by successive deposits of mud, until at length it becomes sufficiently raised to escape being overflowed except by the highest inundations; and even then the stones which are borne along by the current are never lodged upon it.

These soils, so valuable for agricultural purposes, offer, for the most part, but a slight resistance either to the rapid flow of the waters when swollen to a great height at seasons of inundation, and which, therefore, frequently sweeps away portions of them at such times, or to the masses of ice which furrow and tear up their surface at the breaking up of the rivers in spring. I shall therefore briefly point out the means by which these accidents may be avoided; since the preservation of property is of still greater importance than its improvement.

The method most commonly resorted to to prevent the evils of which we have just spoken, is to surround such soils with plantations of trees; but if these be of a kind to grow to a large size, it is evident that they can never be firmly rooted in a sandy moveable soil. The winds, which are generally much stronger in the valleys and along the course of large rivers, shake violently the trees, bend them in every direction, and by this means loosen and move their roots. The earth, too, in contact with these latter, being in this way continually disturbed, the water is freely admitted to render it still more loose, so that when an inundation takes place, it is in these very spots, where the power of resistance has been thus weakened, that the first breaches in the soil will be made.

By carefully observing the action of currents, during seasons of inundation, upon large trees planted on the borders of lands either surrounded by a river, or bounded on one or more sides by its banks, we shall perceive that their trunks presenting a resistance to the water too great to be overcome, the current will thereby be divided, and flowing round the trees, and meeting again on their opposite sides, will have worn away the soil, so as to form trenches which may greatly facilitate the destruction of the property. Thus large trees, although they may indeed turn away the ice, and thus prevent the soil from being injured by it, instead of protecting it against the effects of a rapid current, become in fact its auxiliaries in the work of devastation.

Flexible shrubs are undoubtedly preferable to large trees for the objects here sought to be obtained. They bind together the soil by means of their roots, and by being close to its surface, protect it from injury during times of flood. They do not, however, present sufficient resistance to masses of ice to confine them to the course of the river, and prevent their coming on to the fields to furrow and tear up their surface.

It is necessary then to avail ourselves of the com-

bined effects of the larger trees and of shrubs; and for this object we should either plant willows or poplars on the borders of the banks at the distance of seven or eight feet apart. The tops of these should be cut off a few feet above the elevation of the highest floods, and osiers should be planted, extending from the margin of the bank to the distance of twenty-five or thirty feet back. By adopting this method there will in a few years be nothing to fear either from floods or ice, and a considerable profit also will be derived from the toppings of the trees, and the annual cuttings of the osiers.

After having thus protected our fields against the destructive effects of inundations, we may, by means at once simple and cheap, turn to good account the valuable resources which are afforded by being near a river. I have before remarked that the slime or mud of rivers is the very best substance which can be employed for the amendment of soils, and that on most alluvial lands it renders wholly unnecessary any other manure. It must, therefore, be desirable as much as possible to retain this slime, and especially that portion of it which possesses the most fertilizing properties.

When the water in times of flood has once risen above the level of the upper portion of a field, it passes rapidly over its whole extent, furrowing the surface, and carrying away with it such of the slimy matter with which it is charged, as is composed of the finest particles. It also not unfrequently undermines the crops, and bears away with it the manures that had been deposited by previous inundations; thus impoverishing the soil, in place of enriching it. But when, on the contrary, the overflowing commences at that part of the field which is the lowest down the river, the water gradually extends itself over the whole surface, and being at the same time in a great measure stationary and without current, it deposits the finest portions of its slime, which are by far the

most fertilizing, as being the most abundantly charged with such animal and vegetable substances as have been washed away from the soils, previously passed over; nor is it attended with any bad effects whatever either to the soil or to the crops; and thus the inundation will have proved in every respect highly beneficial. Now to give this upward direction to the water, it is merely required to throw up a barrier of a few feet in elevation around the margin of that part of the field which is highest up the river, and to cover it with osiers.

By such means as these, I have so improved certain islands of which I am the proprietor, in the river Loire, that they have tripled in value. These lands which formerly produced but little, and suffered annually from the floods of the river, are now the most productive of any on my estate, for the cultivation of the beet root and of grain.

When sandy and siliceous soils do not border upon rivers, or if so, are too elevated to admit of being overflowed, their defects in this case can only be corrected by artificial means, as by the employment of the fat marls, clays, manures, &c. These means must be varied according to the nature and the degree of fineness of the sand of such soils, calcareous sand being better adapted to retain moisture than siliceous.

I have seen soils formed principally by beds of coarse pebbles, without any appearance of vegetable mould on the surface, which, nevertheless, produced good crops; the stratum of these stones immediately below the surface containing sufficient earth to admit of the plants taking root, and growing prosperously.

Soils of this nature make the finest pasture lands for sheep, as may be seen on the ancient and very extensive alluvions of the Durance and the Rhone. The herbage on these lands is of the very best quality, its roots being protected by the pebbles from the scorching heat of the sun. Rozier made the experiment of covering the surface of a portion of his vineyards in

the neighbourhood of Bezieres with pebbles, and found that it was followed by favourable results, especially in reference to the quantity of wine produced. A friend of mine was the owner of an enclosure near the barrier d'Enfer in Paris, the soil of which was so dry and poor, that with all his pains he could never succeed in making fruit-trees thrive in it. He at length caused to be spread upon it a covering of good mould, which he had mixed with the dry sand of which the soil was composed, and this gave to it some trifling fertility. The heat, however, so dried up the ground, that he was obliged to have recourse to frequent and very expensive waterings, until he finally determined to cover the entire surface with a layer of pebbles, and from the moment that this was done the trees flourished.

In some countries fire is resorted to, to amend the soil. This process, called *paring* and *burning*, is highly recommended by some agricultural writers, and as strongly condemned by others. These two classes of writers both rest their opinions on the results of experiments made by themselves; they are equally sincere, and it would be useless to dispute the correctness of their observations.

We shall endeavour in some measure to reconcile these contradictory opinions, and to show where the practice of paring and burning may be useful, and where not, by enlightening the agriculturist with regard to the effects of this operation; nor will he be in much danger, after this, of making any other than a judicious and beneficial application of it.

In paring the soil, the sod is taken off in pieces to the depth of from two to four inches; small heaps of combustible materials are at the same time formed, consisting of the heath, thorn-broom, thistles, fern, and shrubs, which foul the soil, and these being covered with the sods, are at the end of a few days set on fire; the combustion continues for a longer or shorter time, and until the mass is reduced to ashes,

After these have become cold, they are spread over the surface of the soil.

By this operation the constituent particles of soils become more finely divided, and they are rendered less compact; the tendency of the clay too freely to absorb water, and its too great adhesiveness, are corrected; the inert vegetable substances are converted into manure; the oxydation of the iron which is present is carried to its maximum, and insects and the seeds of hurtful plants are destroyed, &c.

We may conclude, therefore, that this mode of treatment is beneficial to humid and compact soils, to those which are of too adhesive a nature, or which contain the black oxyde of iron, and to nearly all such soils as are cold, and of a hard and close texture.

The effect of paring and burning a soil is completely to change its character, and to correct in a great measure its imperfections, especially if it be done at a proper time, and in a judicious manner. I have myself, by carrying this operation to the depth of four inches, reclaimed more than one hundred acres of soil that was considered entirely steril, and which was composed almost exclusively of a black ferruginous clay. For twelve years this land, without being particularly productive, has annually given very fair crops. From its previous sterility it had received the name of the Jews' heath.

But this method of treatment should, on the other hand, never be practised on light calcareous soils, nor on such the earthy composition of which is already perfect; neither on fertile soils abounding in decomposed animal and vegetable substances. Nor is this process attended with any good effect in soils that are purely siliceous; inasmuch as they undergo no modification from the action of fire.*

* The improvement of steril lands by burning was known to the Romans. It is mentioned by Virgil in the first book of the Georgics: "*Sæpe etiam steriles incendere profuit agros:*" —Steril soils are improved by frequently burning them. It

In some countries it is the practice to burn the straw upon the field. This method, which can only be considered as a very imperfect imitation of the

is a practice still much in use in many parts of these islands; the theory of its operation has occasioned much discussion, both among scientific men and farmers. It rests entirely upon chymical doctrines; and I trust I shall be able to offer satisfactory elucidations on the subject.

The bases of all common soils are mixtures of the primitive earths and oxyde of iron; and these earths have a certain degree of attraction for each other. To regard this attraction in its proper point of view, it is only necessary to consider the composition of any common siliceous stone. Feldspar, for instance, contains siliceous, aluminous, calcareous earths, fixed alkali, and oxyde of iron, which exist in one compound, in consequence of their chymical attractions for each other. Let this stone be ground into impalpable powder, it then becomes a substance like clay: if the powder be heated very strongly it fuses, and on cooling forms a coherent mass similar to the original stone; the parts separated by mechanical division adhere again in consequence of chymical attraction. If the powder is heated less strongly, the particles only superficially combine with each other, and form a gritty mass, which, when broken into pieces, has the characters of sand.

If the power of the powdered feldspar to absorb water from the atmosphere, before and after the application of heat, be compared, it is found much less in the last case.

The same effect takes place when the powder of other siliceous or aluminous stones is made the subject of experiment.

I found that two equal portions of basalt ground into impalpable powder, of which one had been strongly ignited, and the other exposed only to a temperature equal to that of boiling water, gained very different weights in the same time when exposed to air. In four hours the one had gained only two grains, while the other had gained seven grains.

When clay or tenacious soils are burnt, the effect is of the same kind; they are brought nearer to a state analogous to that of sands.

In the manufacture of bricks the general principle is well illustrated; if a piece of dry briok earth be applied to the tongue, it will adhere to it very strongly, in consequence of its power to absorb water; but after it has been burnt there will be scarcely a sensible adhesion.

The process of burning renders the soil less compact, less tenacious and retentive of moisture; and when properly ap-

process previously described, being confined to the surface of the soil, may, nevertheless, prove beneficial by destroying the weeds, and the seeds deposited by them, and by leaving a slight covering of carbon, which, in consequence of its extreme division, may be made to serve as nutriment to plants. I am of the opinion also that the heat arising from burning the straw and weeds on a soil, may be productive of useful changes in the condition of its constituent principles.

plied, may convert a matter that was stiff, damp, and in consequence cold, into one powdery, dry, and warm; and much more proper as a bed for vegetable life.

The great objection made by speculative chymists to paring and burning is, that it destroys vegetable and animal matter, or the manure in the soil; but in cases in which the texture of its earthy ingredients is permanently improved, there is more than a compensation for this temporary disadvantage. And in some soils where there is an excess of inert vegetable matter, the destruction of it must be beneficial; and the carbonaceous matter remaining in the ashes may be more useful to the crop than the vegetable fibre from which it was produced.

All soils that contain too much dead vegetable fibre, and which consequently lose from one third to one half of their weight by incineration, and all such as contain their earthy constituents in an impalpable state of division, that is, the stiff clays and marls, are improved by burning; but in coarse sands, or rich soils containing a just mixture of the earths, and in all cases in which the texture is already sufficiently loose, or the organizable matter sufficiently soluble, the process of torrefaction cannot be useful.

All poor siliceous sands must be injured by it; and here practice is found to accord with theory. Mr. Young, in his *Essay on Manures*, states, that "he found burning injure sand;" and the operation is never performed by good agriculturists upon siliceous sandy soils, after they have once been brought into cultivation.

An intelligent farmer in Mount's Bay told me that he had pared and burned a small field several years ago, which he had not been able to bring again into good condition. I examined the spot; the grass was very poor and scanty, and the soil an arid siliceous sand.—*Davy's El. Ag. Chym.* pp. 319—325.

The results which I have experienced from the application of calcined clay to a sandy soil in the plain of Sabdons, near Paris, has induced me to believe that to all such soils a similar mixture would prove beneficial. In preparing the clay for this purpose, it is merely necessary, after moistening it, to form it into large balls, and calcine them either in a lime kiln or a potter's oven; these being afterward broken into small fragments, may be employed with good effect in amending calcareous, siliceous, and sandy soils.

Of all the agents which influence vegetation, or which are employed in amending the condition of soils, there is none more powerful than water. Not only does this fluid furnish nutriment to plants by means of its decomposition in their organs, and the deposite of its constituent principles, but it also greatly assists in the fermentation of manures, and constitutes the vehicle by which their salts and juices are conveyed and applied to the purposes of vegetation. In addition to these important uses, water acts as a diluent upon the sap of plants when it has become thickened in their vessels, and thus facilitates its flow, and greatly promotes its transpiration. It likewise divides and opens the soil, so that it is more easily penetrated by the roots of plants, and it is itself enabled thereby the more freely to convey to these latter the atmospheric air with which it is charged.

So much of the water absorbed by plants as is not required for their use, passes off by the pores; and the portion thus transpired is according to their avidity for water, and the quantity of this fluid which they may have imbibed.

It is a common practice to inundate meadows during the winter, for the purpose of protecting them against the effects of severe frosts. Davy, in determining the comparative temperature above and beneath the ice on a meadow which had been thus overflowed, found that while the thermometer was at 29° on the surface of the ice, it stood as high as

43°, below it. There are few persons but must have during the winter observed, that when a meadow is only partially inundated, the herbage on that part of it which has been left dry is withered and apparently almost dead, while, at the same time, that beneath the ice still retains its verdure, and continues to grow.

The kind of water to be employed for purposes of irrigation is by no means a matter of indifference. That which is obtained from living streams is the best, and, especially, when from the length of their course it has become abundantly impregnated with air.

But notwithstanding that water is the most active and important agent in vegetation, it requires to be employed with moderation and prudence. By too copious and long-continued irrigation, the soil is kept constantly in a wet and pastey state, and the worst effects are thereby produced. In the first place, vegetation is injuriously hastened, and plants acquire an inordinate growth at the expense of all the more valuable properties which they ought to possess; since in this state their fibre is loose, their texture soft and watery, their flowers inodorous, and their fruits without consistence, taste, or flavour; and secondly, all such useful plants as do not thrive in lands saturated with water, perish, and in their place there springs up a growth of flags and rushes, which foul and ruin the soil, and thus are produced the very evils we take so much pains to correct in meadows naturally too humid, by the application of soot, gravel, ashes, and other saline and absorbing substances.

Frequently repeated irrigations may be employed, however, without injury, on sandy or calcareous soils, that are light and poor, and that have a very considerable depth; but they never fail, on the contrary, to prove highly injurious to rich, compact, argillaceous soils, which are so congenial to the noxious plants of which we have just spoken.

In order to determine what periods are the most

favourable for irrigation, it is necessary to consult both the state of the crops and the condition of the soil. When the earth has become destitute of moisture to a considerable depth, so that the plants begin to languish, and their leaves to fade, it is a sufficient indication that this operation may be advantageously resorted to. By suffering the plants to remain too long in a drooping and feeble condition, they cease to grow, and hasten to complete their vegetation by the formation of flowers and fruits, which are always diminutive, poor, and imperfect, when produced under such circumstances.*

* *Irrigation, or watering land*, is a practice which, at first view, appears the reverse of torrefaction; and in general, in nature, the operation of water is to bring earthy substances into an extreme state of division. But in the artificial watering of meadows, the beneficial effects depend upon many different causes—some chymical, some mechanical.

Water is absolutely essential to vegetation; and when land has been covered by water in the winter, or in the beginning of spring, the moisture that has penetrated deep into the soil, and even in the sub-soil, becomes a source of nourishment to the roots of the plant in the summer, and prevents those bad effects that often happen in lands in their natural state, from a long continuance of dry weather.

When the water used in irrigation has flowed over a calcareous country, it is generally found impregnated with carbonate of lime; and in this state it tends, in many instances, to ameliorate the soil.

[And, I may add, to counteract the effect of rain-water, to dissolve and remove carbonate of lime from the soil. In Malta, where irrigation is much employed, the water containing carbonate of lime, I have found no deficiency of this compound in the soil of the irrigated lands; but in England, even in chalk districts, the superficial soil is often entirely destitute of carbonate of lime; it has been removed in process of time, supposing that it previously existed in the soil, by the solvent power of rain-water.—*J. D.*]

Common river-water, also, generally contains a certain portion of organisable matter, which is much greater after rains than at other times; and which exists in the largest quantity when the stream rises in a cultivated country.

Even in cases when the water used for flooding is pure, and

The practice of leaving lands in a fallow state, or allowing them to rest after a succession of crops, is of very great antiquity, and still continues to constitute the basis of the agricultural system pursued at the present day, in most parts of Europe. After a soil has become exhausted by the production of two or three successive crops, it is believed to be necessary that it should have rest, or lie fallow for one or two years, that it may recover its fertility, and its productive powers.

The necessity of rest, which nature has imposed upon all animals, when they have become fatigued and exhausted by continued labour, or by long protracted efforts, doubtless contributed to the adoption of this mode of culture; and, although the analogy free from animal or vegetable substances, it acts by causing the more equable diffusion of nutritive matter existing in the land; and in very cold seasons it preserves the tender roots and leaves of the grass from being affected by frost.

Water is of greater specific gravity at forty-two degrees Fahrenheit, than at thirty-two degrees, the freezing point; and hence in a meadow irrigated in winter, the water immediately in contact with the grass is rarely below forty degrees, a degree of temperature not at all prejudicial to the living organs of plants.

In 1804, in the month of March, I examined the temperature in a water meadow near Hungerford, in Berkshire, by a very delicate thermometer. The temperature of the air at seven in the morning was twenty-nine degrees. The water was frozen above the grass. The temperature of the soil below the water in which the roots of the grass were fixed was forty-three degrees.

In general those waters which breed the best fish are the best fitted for watering meadows; but most of the benefits of irrigation may be derived from any kind of water. It is, however, a general principle, that waters containing ferruginous impregnations, though possessed of fertilizing effects, when applied to a calcareous soil, are injurious on soils that do not effervesce with acids; and that calcareous waters, which are known by the earthy deposit they afford when boiled, are of most use on siliceous soils, or other soils containing no remarkable quantity of carbonate of lime.—*Davy's El. Ag. Chym.* pp. 325—327.

thus sought to be established between living bodies and those which are inanimate, is without the slightest foundation either in nature or reason, it has nevertheless had something to do in perpetuating the practice of fallowing.

Still I am far from thinking that the cause just mentioned was the principal one, for adopting this practice; since it is much more reasonable to attribute both its introduction and continuance, for the most part at least, to a deficiency of agricultural labourers, and the difficulty of feeding a sufficient number of animals to furnish a requisite quantity of manure.

The extent of soil under culture will be proportioned to the population that is to be supported by its products. It may, therefore, be presumed that, at a time when the earth had fewer inhabitants, the most fertile lands would be first occupied, and, so soon as these became exhausted, others in turn would be resorted to. But when the rights of property came to be better defined and established, and lands were marked out and secured to their occupants, each cultivator would subject to tillage only such a proportion of his soil as might be required to supply his wants; so that he would perhaps find it necessary merely to cultivate a third or fourth part of his land, and would leave the rest untouched.

Fallowing then, admitting the views which we have here advanced to be correct, was in the first instance a matter of necessity. We may perceive from the productiveness of the gardens around our dwellings, that, with a sufficiency of labour and of manures, crops may be extended and multiplied indefinitely; but we do not feel any necessity for this, inasmuch as what is already produced suffices to supply all the demands of consumption, and any expenditure, therefore, for the purpose of increasing the returns of agriculture beyond their present amount, would be only so much clear loss.

In the progress of population, additional lands have been occupied and subjected to tillage, cultivation has been extended and improved, and thus production has been constantly kept up to the level of consumption.

The necessities of society at the present day no longer admit of the same extent of fallows as formerly, and thus they are beginning to disappear, wherever these necessities are most pressing, and wherever there is assurance of a remunerating market for the products of agriculture.

And how, it may be asked, could fallows formerly be suppressed, while the cereal plants, which so greatly exhaust the soil, were alone cultivated? By withholding land from tillage, pasture was afforded to cattle, and the herbage turned in by the plough furnished a great part of the manure required for following crops of grain. But at the present day, with our artificial meadows, and the successful cultivation of so great a variety of roots, the system of fallows is no longer to be tolerated; nor can it be supported by a single argument that is entitled to the smallest consideration.

The want of manure, owing to the small number of animals that could be fed, has perpetuated the practice of which we have been speaking; but the facility of raising fodder now experienced, affords the means of supporting a larger stock of animals, while these, in their turn, contribute both manure and labour, and thus the agriculturist is no longer under any necessity of being deprived of the use of his lands in a state of fallow.

Artificial meadows should now be made to constitute the basis of agriculture; since it is these which give to us fodder, and it is fodder which gives to us a greater number of domestic animals, and from these we may obtain labour, manure, and, in short, everything that is required for good husbandry.

The abandonment of fallows is highly advantageous to the farmer, inasmuch as he is enabled there-

by to increase his products without a proportionate increase of expenditure; nor is it less beneficial to society at large, by obtaining from the same surface a greatly increased amount of food, and a more abundant supply of raw material for the purposes of manufacture.

Nor is increased production the only benefit which agriculture may derive from the suppression of fallows. By a judicious rotation of crops, the cereal, herbageous, and leguminous plants, and roots, &c., succeeding each other in a properly arranged order, the soil is rendered more productive, instead of being impoverished, weeds are extirpated, and more abundant crops are obtained at a diminished cost. During the years, also, in which certain kinds of fodder, such as luserne, sainfoin, and clover, demand only the care of harvesting, the farmer may give his whole attention, and employ all his manures and the labour of his cattle, in the melioration and amendment of such portions of his soil, as he may find to be in need of it; so that, instead of leaving one third of his arable land in unproductive fallows, he may have it covered with herbage, affording an excellent product, enriching his soil in place of making it poorer, and preparing it, without other manure, for succeeding crops of grain.*

* There is an operation of very ancient practice still much employed, in which the soil is exposed to the air, and submitted to processes which are purely mechanical, namely, *fallowing*.

The benefits arising from fallows have been much overrated. A summer fallow, or a clean fallow, may be sometimes necessary in lands overgrown with weeds, particularly if they are sands which cannot be pared and burnt with advantage; but is certainly unprofitable as part of a general system in husbandry.

It has been supposed by some writers, that certain principles necessary to fertility are derived from the atmosphere, which are exhausted by a succession of crops, and that these are again supplied during the repose of the land, and the exposure of the pulverised soil to the influence of the air; but this is not a correct statement. Oxygen is absorbed by the

Nothing has contributed so much toward retaining the agriculture of France in its present state of mediocrity, and from which neither the example nor the

vegetable film, and, perhaps, in certain cases, azote; but the earths, the great elements of soils, cannot be combined with new elements from the air; none of them unite to azote; and such of them as are capable of attracting carbonic acid, are always saturated with it in those soils on which the practice of fallowing is adopted. The vague ancient opinion of the use of nitre and of nitrous salts in vegetation, seems to have been one of the principal speculative reasons for the defence of summer fallows. Nitrous salts are produced during the exposure of soils containing vegetable and animal remains, and in greatest abundance in hot weather; but it is probably by the combination of azote from these remains with oxygen in the atmosphere that the acid is formed, and at the expense of an element which otherwise would have formed ammonia; the compounds of which are much more efficacious than the nitrous compounds in assisting vegetation.

When weeds are buried in the soil, by their absorption of oxygen and gradual decomposition they furnish a certain quantity of soluble matter, and a soil will certainly in consequence produce better crops at the end of a fallow; but the use of this practice must depend upon the quantity of vegetable fibre and its nature, and upon the quality of the soil. Carbonic acid gas is formed during the whole time by the action of the vegetable matter upon the oxygen of the air, and the greater part of it is lost to the soil in which it was formed, and dissipated in the atmosphere.

The action of the sun upon the surface of the soil tends to disengage the gaseous and the volatile fluid matters that it contains; and heat increases the rapidity of fermentation: and in the summer fallow, nourishment is rapidly produced, at a time when no vegetables are present capable of absorbing it.

Land, when it is not employed in preparing food for animals, should be applied to the purpose of the preparation of manure for plants; and this is effected by means of green crops, in consequence of the absorption of carbonaceous matter in the carbonic acid of the atmosphere. In a summer's fallow a period is always lost in which vegetables may be raised, either as food for animals, or as nourishment for the next crop; and the texture of the soil is not so much improved by its exposure as in winter, when the expansive powers of ice, the gradual dissolution of snows, and the alterna-

writings of her most enlightened agriculturists have yet availed to raise it, as the passion, so general among farmers, to keep under tillage a great extent

tions from wet to dry, tend to pulverize it, and to mix its different parts together.

It is a great advantage in the convertible system of cultivation, that the whole of the manure is employed; and that those parts of it which are not fitted for one crop remain as nourishment for another. Thus, in Mr. Coke's course of crops, the turnip is the first in the order of succession; and this crop is manured with recent dung, which immediately affords sufficient soluble matter for its nourishment; and the heat produced in fermentation assists the germination of the seed and the growth of the plant. After turnips, harley with grass seeds is sown; and the land, having been little exhausted by the turnip crop, affords the soluble parts of the decomposing manure to the grain. The grasses, rye-grass, and clover remain, which derive a small part only of their organized matter from the soil, and probably consume the gypsum in the manure, which would be useless to other crops: these plants, likewise, by their large systems of leaves, absorb a considerable quantity of nourishment from the atmosphere; and when ploughed in at the end of two years, the decay of their roots and leaves affords manure for the wheat crop: and at this period of the course, the woody fibre of the farm-yard manure, which contains the phosphate of lime and the other difficultly soluble parts, is broken down; and as soon as the most exhausting crop is taken, recent manure is again applied.

Mr. Gregg, whose ingenious system of cultivation has been published by the Board of Agriculture, and who has the merit of first adopting a plan similar to Mr. Coke's upon strong clays, suffers the ground after barley to remain at rest for two years in grass: sows peas and beans on the leys; ploughs in the pea or bean stubble for wheat; and in some instances follows his wheat crops by a course of winter tares and winter barley, which is eaten off in the spring, before the land is sowed for turnips.

Peas and beans, in all instances, seem well adapted to prepare the ground for wheat; and in some rich lands, as in the alluvial soil of the Parret, and at the foot of the South Downs in Sussex, they are raised in alternate crops for years together. Peas and beans contain a small quantity of matter analogous to albumen; but it seems that the azote, which forms a constituent part of this matter, is derived from the

of soil, without proportionate means for its due and proper cultivation. The seed is sown without any suitable preparation of the soil, the land is everywhere exhausted instead of being enriched, and the farmer is without interest in its improvement, since the shortness of his lease affords to him no promise of enjoying the fruits of his labour; so that he thinks of nothing more than merely to live from day to day.

Instead of extending his cultivation beyond the means at his disposal, the first care of the intelligent agriculturist should be to improve such a portion of his land, as is requisite to support his stock, and furnish to him the necessary manure for a progressive melioration and amendment of his soil. When this has been brought into a suitable state, and a judicious succession of crops has been established, he will successively extend his improvements to other parts of his land, and, in this way, will, step by step, render every portion of his soil highly fertile, so as in a few years to obtain from it all that it can be made capable of producing. But it is only by a system of long leases that this state of things, so desirable, can be brought about; and the farmer be enabled to pursue a course of husbandry at once so enlightened, and so surely profitable. Nor would such a system be in any degree less advantageous to the landed proprietor, than to his tenants.

Being the owner of a very extensive domain, I have not hesitated to divert from tillage about two hundred and fifty acres of land of inferior quality, which, notwithstanding that it was annually manured equally with my best soils, afforded to me but scanty crops. At present, the whole of this land is covered with herbage, and employed for the pasturage of my cat-

atmosphere. The dry bean leaf, when burnt, yields a smell approaching to that of decomposing animal matter; and in its decay in the soil, may furnish principles capable of becoming a part of the gluten in wheat.--*Davy's El. Ag. Chym.* pp. 327—332.

tle and sheep. One fifth of it I have annually broken up and sown with oats, barley, or rye, and again converted into pasture the following year. I am satisfied that I never could have obtained any remunerating returns from this land, by the cultivation of grain, roots, and pulse.

CHAPTER VIII.

On the Selection of Soils, and Rotation of Crops.

[FROM CHAPTAL'S CHYMISTRY APPLIED TO AGRICULTURE.]

By means of great labour, enormous expense, and the application of manure without measure, the same soil may be made to yield all sorts of plants; but it is far from being in a system of management like this, that agricultural science should be made to consist. Agriculture is not to be carried on either as a matter of fancy or of luxury; and whenever its products fail liberally to repay the expenditure both of money and of labour bestowed upon them, it may be assumed at once that the system pursued is wrong.

A skilful and discreet agriculturist will first of all consider attentively the nature and properties of his soil, that he may determine to what particular course of culture it is best adapted; and of this he will be able to judge either by the character of the plants which grow spontaneously upon it, or by sowing it with different seeds by way of experiment. Nor will he be satisfied to cultivate promiscuously, and without change, even such plants as he finds suited to the soil and climate; since the productive powers of soils become greatly diminished by cultivating upon them uninterruptedly, the same plants. In order, therefore, that he may ensure a constant succession of good

crops, he will cultivate different kinds of plants in rotation upon the same fields; and he will also have these to follow each other in such order as experience shall show to be most favourable to their growth, avoiding altogether the introduction of such plants, as are unsuited to the soil. It is this changing of crops, this alternate culture of different kinds of plants, regulated by experience of their respective effects upon the soil, which constitutes that judicious order of succession, so indispensable to prosperous husbandry.

Such a system of rotation affords, in my estimation, the best of all guarantees to the farmer, of success in his operations; and without it, I consider all to be vague, uncertain, and hazardous.

But in order to establish an enlightened system of rotation of crops; it is required that we should first make ourselves acquainted with the principles on which it must be founded; and in respect to which, unfortunately, our writers upon agriculture have manifested, for the most part, no little ignorance.

I will endeavour, then, to bring together such facts, and state such principles as shall serve rightly to direct us in this important branch of husbandry; and for more extensive and minute information, I cannot do better than to refer my readers to the excellent works of Yvart and Pictet, on this subject.*

PRINCIPLE I.—*All plants exhaust the soil.*

It is the earth which gives support to plants; and the juices with which it is impregnated constitutes their principal nourishment. Water serves as the vehicle for conveying these juices into their organs, and for presenting them to the fibres of the roots, to be absorbed by them. It is evident, therefore, that the process of vegetation must constantly tend more and more to exhaust the soil; so that unless its nu-

* "*Cours complet d'agriculture*," articles *Assolement et succession de culture*, par Yvart—" *Traité des Assolements*," par Ch. Pictet.

tritive juices be from time to time renewed, it must eventually become entirely steril.

Thus a soil that has been once well manured, may, without any intermediate additional supply, be made to produce in succession several crops; but they will be seen progressively to degenerate, until finally the soil becomes completely exhausted.*

PRINCIPLE II.—*Plants do not all exhaust the soil in the same degree.*

Plants are nourished by the air, water, and the juices of the soil; but their different kinds do not all consume the same quantity of nutriment. There are those which require that their roots should be constantly immersed in water; some affect a soil that is barren and dry, while others, again, thrive only in soils that are rich and highly manured.

The cereal plants and most of the grasses throw up

* Strawberries and potatoes at first produce luxuriantly in virgin mould recently turned up from pasture; but in a few years they degenerate, and require a fresh soil; and the organization of these plants is such, as to be constantly producing the migration of their layers: thus the strawberry by its long shoots is constantly endeavouring to occupy a new soil; and the fibrous radicles of the potatoe produce bulbs at a considerable distance from the parent plant. Lands in a course of years often cease to afford good cultivated grasses; they become, as it is popularly said, tired of them.

The most remarkable instance of the powers of vegetables to exhaust the soil of certain principles necessary to their growth is found in certain funguses. Mushrooms are said never to rise in two successive seasons on the same spot, and the production of the phenomena called fairy rings has been ascribed by Dr. Wollaston to the power of the peculiar fungus which forms it, to exhaust the soil of the nutriment necessary for the growth of the species. The consequence is, that the ring annually extends, for no seeds will grow where their parents grew before them, and the interior part of the circle has been exhausted by preceding crops; but where the fungus has died, nourishment is supplied for grass, which usually rises within the circle, coarse, and of a dark green colour.—*Davy's El. Ag. Chym.* pp. 333, 334.

long stems, consisting chiefly of fibrous matter; and these are furnished at their foot with a few leaves, which, on account of the compactness of their texture, and the small surface which they present, can absorb, comparatively, but little either of air or water. These plants therefore derive their nourishment principally from the soil, and their stalks are employed either for litter or food for animals; so that while they greatly exhaust the soil, they return scarcely anything to it; their stalks being cut and taken away from the ground for the purposes just mentioned, and their roots, which alone remain, being dried up and drained of all their juices, in the process of forming and of maturing the seed.

Plants, on the contrary, abundantly furnished with large, thick, porous leaves, that are constantly green, imbibe from the atmosphere carbonic acid and oxygen, and draw from the earth such other substances as they require for their nourishment. When plants of this kind are cut in a green state, the loss of nutritive juices sustained by the soil is less sensibly felt, inasmuch as these are in part given back to it by the roots. Such plants as are usually cultivated for fodder are nearly all of this description.

There is another class of plants, which, though cultivated principally for their seed, are less exhausting to the soil than the cereal plants; we refer to the numerous family of legumes, which holds an intermediate place between the two classes of which we have just spoken. The long perpendicular roots of the leguminous plants divide the soil, and their large leaves, and thick, soft, spongy stems, readily absorb both air and water. The different parts retain for a long time the juices with which they are so abundantly impregnated, and give them back to the soil, when the plants are ploughed in at a period before they become mature; and by this means alone, the soil may be put in a condition to produce a good crop of grain. Beans are particularly valuable in this re-

spect; while vetches and peas, and more especially the latter, are less fertilizing in their effects.

Generally speaking, if plants be cut in a green state, and at the time they are in flower, whatever may be their particular nature, they do not exhaust the soil; since up to this period they have drawn their nourishment almost exclusively from the earth, air, and water. Both their stalks and roots abound in juices, and the parts remaining after the former are cut, return to the soil all that has been taken from it for the support of the plants.

But as soon as the seed once begins to form, the process of nutrition undergoes a change. The plant, as before, still abstracts nutritive principles from the earth and atmosphere; but in addition to this, it now resorts to the juices contained in its stalks and roots, and these likewise are made to contribute to the formation of the seed; so that, from this time, the stalks and roots are both gradually dried up and exhausted; and when at length the seed has reached maturity, the skeleton merely of the plant remains, and this, on being given back to the soil, returns to it but a very inconsiderable portion of what it had previously taken from it.

Oleagenous seeds exhaust the soil more than farinaceous; and the agriculturalist cannot be too careful to rid his land of weeds of the former character, all of which are highly exhausting, and especially the wild mustard, [*sinapis arvensis*,] with which cultivated fields are so liable to be infested.

PRINCIPLE III.—*Different kinds of plants do not exhaust the soil in the same manner.*

The roots of plants, whether of the same species or family, extend themselves in a similar manner; penetrating to the same depth, growing of the same length, and exhausting all that portion of the soil which they encompass, or with which they come in contact.

Such roots as run nearest the surface, and occupy

the least space, are the most divided. Perpendicular roots that penetrate far into the earth, throw out but few radicles near the surface, and draw their nourishment from a considerable depth. If in transplanting a turnip or beet, the point of the tap-root be cut off, so that it can no longer run down into the soil for nourishment, it will send out small fibrous roots from all parts of its surface, which extending to a certain distance, absorb the nutritive principles from such portions of the soil as they are able to reach; and in this case the form of the root will be roundish instead of being tapering and long.

It would appear, then, that the roots of plants exhaust only such portions of the soil as are in contact with them; and thus long perpendicular roots may be enabled to obtain from a soil abundant nourishment, even when its upper portion has been completely exhausted by such as naturally run near the surface.

The roots of plants of the same species, and of such also as are of analogous character, uniformly extend themselves in a similar direction, whenever the character of the soil prevents not their free development; so that they all occupy the same stratum of earth, and are nourished by it. Hence it is that trees rarely flourish when, in the same ground, they are made to succeed others of the same species; and especially when sufficient time has not intervened for the roots of the first to decay, so as to afford to the stratum of soil occupied by them, a fresh supply of manure.

That different kinds of plants do not exhaust the soil in the same manner, would seem to be sufficiently evident from the simple fact, that plants are not nourished by a mere mechanical process. They do not absorb indiscriminately, and in like proportions, all the different salts and juices that may be presented to them; and to whatever we ascribe it, whether to vital action, or to the peculiar conformation of their

organs in exercising an influence over the nutritive process, it is certain that they have themselves a preference for particular substances; as has been sufficiently proved by the experiments both of de Saussure and of Davy. Thus with regard to plants as well as animals, while there are some alimentary substances suited to all, there are others again which are appropriate only to particular species. The truth of this is abundantly evinced by the choice manifested by certain plants in selecting particular salts, in preference to others of a different nature.

PRINCIPLE IV.—*Plants do not all return to the soil either the same quantity or kind of manure.*

All plants more or less exhaust the soil of its nutritive juices; but, on the other hand, they all likewise restore to it, in the remains they leave behind them, something in a degree to repair this loss. The cereal and oleagenous plants are the most exhausting of all, and at the same time return the least to the soil. When plants, in being gathered, are pulled up with their roots, they do not leave anything to repay for the nourishment which they have received.

It is true that other kinds of plants consume, in seeding, a large proportion of the manure which is contained in the soil; but then the roots of a part of these penetrate far into the soil, separate its parts, and render it loose and open to a great depth; while others, again, cover its surface with their numerous leaves, and these being detached from their stalks during the progress of vegetation, compensate in part for what has been taken from it. There are some plants, also, the stalks and roots of which still retain their succulence even after their fruit is matured; and which, therefore, in their decomposition, restore to the soil a portion of the juices of which they had deprived it; certain of the legumes are of this character.

Different kinds of plants, which are not ordinarily

left to perfect their seed, exhaust the soil but little, and may be introduced, with great advantage, into a succession of crops; since, by employing them in this way, the same ground may be kept productive for a series of years, without any new application of manure; different kinds of clover, and especially luserne and sainfoin, are of this latter description.

PRINCIPLE V.—*Plants do not equally foul the soil.*

Plants are said to foul the soil when they encourage or permit the growth of noxious weeds, which exhaust it of its alimentary principles, crowd the useful plant, and thereby obstruct its growth, and, by appropriating to themselves a portion of its nourishment, accelerate its decay. All plants not supplied with large and spreading leaves, so as completely to cover the soil on which they grow, are of the class we are now considering.

The cereal plants, therefore, take precedence of all others in this respect; since their tall, slender stalks, and long, narrow leaves but very partially shade the ground, and thus not only permit such weeds as are natural to the soil to spring up in their intervals, but also encourage their growth by the protection which they afford to them against the heat and winds.

Herbaceous plants, on the other hand, their stalks rising only to a moderate height, and their leaves covering the entire surface of the soil, effectually prevent the growth of everything about their roots, and consequently the soil is kept clean, and free from weeds. It must, however, be remarked, that this latter effect will only be produced, where the soil is suited to the growth of the plants, and at the same time abundantly supplied with manure, so that there shall be a luxuriant and vigorous vegetation; since, in cases where these favourable circumstances do not exist, we shall observe the same plants to be in a feeble and languishing condition, so that they become gradually overshadowed by others of a more sturdy;

and less useful character, until at length they are entirely displaced by them.

When plants are cultivated in furrows, as is the case with roots and most of the legumes, large intervals are left which become occupied by weeds; the soil however may be kept clean in this kind of culture, by frequently passing over it with the hoe, or with some other suitable implement; and it may in this way be maintained in a state sufficiently fertile to produce another crop, especially if the plants growing upon it be not suffered to mature their seed.

The seeds of weeds are often mixed with those of the useful plants, and sown at the same time; nor can the farmer be too careful in avoiding this. But much more frequently these seeds are conveyed by the winds, or deposited by water, or committed to the soil along with the manure.

The improvidence of such farmers as suffer thistles and other noxious plants to grow and seed about their fields, cannot be too severely censured; since these plants fail not, each successive year, to reproduce other and more abundant crops, until at length they become multiplied to such an extent, that it is difficult, and sometimes almost impossible, to rid the soil of them. This negligence is often carried so far, that whilst the grain is cut about the thistles, these latter are still left standing to perfect undisturbed the maturing of their seeds. How much more rational and profitable it would be to cut down these noxious plants before they flower, and turn them to useful account by converting them into manure, instead of suffering them to remain and exhaust the soil, obstruct and impoverish the crops, and annually to propagate a constantly increasing progeny of the same pernicious race.

From the several principles then here laid down, we may derive the following conclusions:—

1st. That, however fertile and well prepared a soil may be, it cannot be made to produce a long succes-

sion of crops of the same kind, without becoming exhausted.

2d. Every crop empoverishes the soil more or less; and in proportion as the plants cultivated return to it in their remains a greater or less amount of nutriment.

3d. The culture of plants having long perpendicular roots should be made to succeed that of those with spreading and superficial roots.

4th. We should avoid a too frequent return of plants either of the same, or of analogous species, on the same soil.*

5th. Two different kinds of plants, both tending to foul the soil, should not immediately succeed each other.

6th. Plants which derive their principal nourishment from the earth, should be cultivated only in such soils as are sufficiently enriched by manures.

7th. In proportion as a soil becomes exhausted by continual cropping, those plants should be cultivated which give back to it in their remains, the greatest quantity of manure.

The principles here stated have been abundantly confirmed by experience, and they constitute the basis of an agriculture rich in products, and economical in the highest degree, from the great saving which it

* In addition to the reasons already offered why plants of the same kind should not succeed each other upon the same soil, there are some others which I will briefly state. M. Olivier, member of the French Institute, has very carefully and minutely described all the different insects which prey upon the neck of the roots of the cereal plants, and which multiply almost to infinity, when in the same soil they are presented with the same, or with analogous species of plants, for many years in succession; whereas these same insects are all made to perish, whenever such plants as do not furnish the necessary aliment to their larvæ, are introduced in place of grain. These insects are of the family of tipulæ, or that of flies.—*Sixteenth volume of the Memoirs of the Royal Central Agricultural Society of Paris.*

produces both of labour and manure. These principles should be made to regulate the practice of every agriculturist, though their application requires to be modified by the nature of soils, diversities of climates, and the respective wants of different localities.

To recommend a particular rotation of crops without regard to the dissimilar nature and properties of soils, would be to bring into question the system itself in the eyes of those agriculturists, who are as yet insufficiently enlightened to adopt in their modes of cultivation the changes which it would require.

Luserne and sainfoin are classed among the plants which should have a place in the system of a rotation of crops. Nevertheless, it is to be remembered that these plants require a deep soil, and at the same time not too compact, in order that they may freely penetrate the earth with their long perpendicular roots.

Hemp, flax, and the cereal plants, require good ground, and should not be admitted into a course of crops, except in such soils as are abundantly fertile and thoroughly prepared.

Light, dry soils are unsuited to the same succession of plants, as would be appropriate to those of a compact nature, and which are constantly humid.

Each kind of soil, therefore, demands a particular course of crops; and every agriculturist should arrange his system according to the nature and properties of the soil which he has to cultivate.

Inasmuch as in each different situation, soils will present some shades of dissimilarity, more or less distinctly marked, according to their exposure, depth, composition, &c., the farmer should vary his cultivation in conformity to these differences, and adopt for each kind of soil the course of crops to which it is best suited.

The wants of his own particular locality, the greater or less facility in getting his products to market, and the relative value of different crops, should also influence him in forming his plans of cultivation.

In England, and in some of the northern countries

of continental Europe, barley is made frequently to recur in a course of crops, for the reason that in these countries there is a sure and constant demand for this kind of grain, to supply their numerous breweries. In Belgium, on the borders of the Rhine, and in Russia, rye is very extensively cultivated, since the immense distilleries in these countries, and the feeding of a multitude of animals upon the remains of the grain, and other refuse matter furnished by these establishments, secure to it a certain and profitable sale. The culture, again, of plants made use of for the colouring matter which they contain, as woad and madder, is more advantageous in the neighbourhood of large dying establishments, than in countries where there is no consumption of these articles. In France, where the abundance and the low prices of wine hold out no prospect of an extensive demand for malt liquors, and where most of the people are accustomed to live chiefly upon bread made of wheat, this particular grain is cultivated in preference wherever it can be made to grow, while only the inferior soils are appropriated to the other kinds.

There is still another consideration which should be well weighed by the farmer, before he decides upon his course of crops. Although his soil may be well adapted to a particular culture, his interest may, nevertheless, be opposed to the pursuit of it. The more abundant a commodity is, the more reduced it will be in price; and those articles should always be cultivated in preference, which will command the readiest sale, and afford the most remunerating returns. When, too, any product is not expected to be consumed upon the spot, the expense of its transportation to a market must be considered, and the facility with which it may be disposed of.

The landed proprietor should first make liberal provision for his domestic animals, and his household, and the labourers on his estate, before he thinks of raising any surplus products to be sent abroad. He

will therefore so arrange his system of husbandry that his lands shall at all times present such a variety of crops, as will ensure subsistence to all employed in, or immediately dependant upon their cultivation.

The intelligent agriculturist will likewise endeavour as much as possible to diminish the labour and expense of transport, in the culture and management of such of his lands as are remote from his dwelling; and with this object, he will cultivate in preference on lands so situated, either crops of fodder and roots that may be consumed by his animals upon the spot, or such herbaceous or other plants as may be converted into manure, by being turned into the soil.

He should be careful also, in the treatment of such of his lands as are of a light and open character, and at the same time so situated as to have a considerable descent, to cultivate in them such plants only as will cover the surface with their numerous leaves, and the roots of which will bind together every part of the soil, so that it shall be protected as well from being washed away by the rains, as from being dried up by the intense heat of the sun.

And, now, in order to support by examples the soundness of the principles here advanced, I will briefly notice the different courses of cropping which have been adopted in those countries, where agriculture is admitted to be the most intelligently conducted, and with the most prosperous results; and, in doing this, I will begin with the provinces of ancient Flanders, where correct and enlightened husbandry had its birth.

In the arrondizement of Lille, and Douai, where the soil is of the best quality, and where the art of preparing and applying manures is carried to the highest state of perfection, the following courses of crops are generally adopted :—

First Course. Flax or rape.

Wheat.

Beans.

Oats with clover.

Clover.

Wheat.

Second Course. Turnips.

Oats or barley with clover.

Clover.

Wheat.

Third Course. Potatoes.

Wheat.

Roots, such as turnips or beets.

Wheat.

Buckwheat.

Beans.

Oats and clover.

Clover.

Wheat.

We perceive in these several courses of crops, that, after a soil has been manured, the most exhausting plants and those which are least so, are made to alternate with each other; while such as foul the soil are succeeded by others, in the cultivation of which it is required to be kept clean by frequent weedings.

It is by such means as these that nearly all that part of Belgium which borders upon the sea, and the soil of which is naturally a barren sand, has been brought to a state of fertility equalling that of the very best lands, and is now made everywhere to produce the richest and most abundant harvest.

On the sandy soils in the neighbourhood of Brussels, Ostend, Nieuport, Antwerp, &c., the culture of the cereal plants is judiciously interchanged with beans, cabbage, potatoes, and carrots. The Norfolk system of husbandry, so much extolled in England

consists in commencing the rotation with the culture of roots in a soil well manured, and which is afterward followed by barley or oats, and lastly by wheat.

In the bed of dry and barren sand composing the soil of Campine, one may also see with what success its industrious inhabitants have overcome every obstacle, so as to render it, notwithstanding all its forbidding qualities, fertile and productive. We are not a little surprised to witness on these sandy plains, a highly flourishing agriculture, which is still undergoing constant improvement from a judicious course of cropping. The rotation here adopted is as follows:

Potatoes.

Oats and clover.

Clover.

Oats and broom (*genistella herbacea*) the same year.

Turnips.

In a journey which I made in company with Napoleon, into Belgium, I heard him express to the counsellor-general of the department which he had then just passed over, his surprise at the great extent of land covered with heath, and in a state of waste; and to which the following reply was made: "Give to us a canal by which we may obtain manures, and transport our products to a market, and in five years these same wastes will be covered with crops." The canal was forthwith constructed, and the pledge here given realized in even less time than had been demanded.

In the interior of France, where fodder constitutes the principal nourishment of animals, and where its place cannot be supplied, as in more northern countries, by the wash of distilleries and breweries, and the grains that are made use of in such establishments, the cultivation of the herbaceous plants should be greatly extended, and more frequently interchanged with crops of grain.

On all my compact soils, and where they are in any degree of an argillaceous character, and of considerable depth, after causing them to be thoroughly

manured, I commence my rotation with beets, and this I follow with wheat, sowing it immediately after the roots are gathered, and without any intermediate tillage; while this last is succeeded by the artificial grasses, and these, again, by oats. When the land is of a very superior quality, after wheat I sow luserne, and then in turn the cereal plants, and roots.

On such of my light soils are deep, and of a sandy character, but nevertheless moist, as those upon the banks of the Loire, which are overflowed once or twice during the winter, I sow in the first place winter vetches, which produce abundantly, and these I succeed with beets.

Independent of the use which I find for this root in supplying my sugar manufactory, I consider its cultivation to be of all others the most advantageous, from the quantity of food which it supplies for the support of animals. Cattle may be fed with its leaves during the months of August and September, by gathering such of them only as have completed their growth, while the roots themselves yield a most abundant and a highly nutritive crop, of not less than from twenty to thirty thousand pounds to the acre.

In a course of crops for lands of a very superior quality, such, for instance, as besides containing all the requisite earthy constituents, are of good depth, with a favourable exposure, and suitably manured, all plants adapted to the climate may be freely introduced; but this is not the case with soils of a different character, that are deficient in some of these qualities.

On siliceous and calcareous soils, which are generally dry, the course of culture may be made to consist of an interchange of rye, barley, spelt along with sainfoin, lupines, lentils, French beans, chickpeas, radishes, woad, buckwheat, potatoes, &c.; preference being always given to such of these as experience may have shown to be best adapted to the soil and

climate, and such also as yield the most profitable returns to the farmer.

In compact soils, the character of which is improved by a due proportion of clay, and which are suited to wheat, the course of cropping may include wheat, oats, clover, luserne, vetches, beans, turnips, radishes, cabbages, rape, &c.

For all soils, the rotation should consist of such plants as suit them best, and it should be arranged in strict conformity to the principles here laid down.

The advantages derived from a judicious and well-conducted course of cropping, are, that it economizes labour, manure, transport, &c.; that it ensures an increase of products without a corresponding increase of expenditure; that it enables the farmer to raise and feed a much larger stock of animals; and that it ameliorates the condition of lands to such an extent as to change their nature, so that the most delicate and exhausting plants may be made to flourish in soils which were before sterile and ungrateful. The barren sands of a great part of Belgium, and many of the alluvions along the borders of our great rivers, afford numerous examples in confirmation of these facts.

An enlightened and judicious system of alternating crops, affords, then, the only guarantee of durable success in husbandry.

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